U.S. Department of the Interior
U.S. Geological Survey

MINERALS YEARBOOK

Metals and Minerals 2005

Volume I

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U.S. DEPARTMENT OF THE INTERIOR
DIRK KEMPTHORNE, Secretary

U.S. GEOLOGICAL SURVEY
Mark D. Myers, Director

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Foreword

This edition of the U.S. Geological Survey (USGS) Minerals Yearbook discusses the performance of the worldwide minerals and materials industries during 2005 and provides background information to assist in interpreting that performance. Content of the individual Minerals Yearbook volumes follows:

- Volume I, Metals and Minerals, contains chapters about virtually all metallic and industrial mineral commodities important to the U.S. economy. Chapters on survey methods, summary statistics for domestic nonfuel minerals, and trends in mining and quarrying in the metals and industrial mineral industries in the United States are also included.
- Volume II, Area Reports: Domestic, contains a chapter on the mineral industry of each of the 50 States and Puerto Rico and the Administered Islands. This volume also has chapters on survey methods and summary statistics of domestic nonfuel minerals.
- Volume III, Area Reports: International, is published as four separate reports. These regional reports contain the latest available minerals data on more than 180 foreign countries and discuss the importance of minerals to the economies of these nations and the United States. Each report begins with an overview of the region's mineral industries during the year. It continues with individual country chapters that examine the mining, refining, processing, and use of minerals in each country of the region and how each country's mineral industry relates to U.S. industry. Most chapters include production tables and industry structure tables, information about Government policies and programs that affect the country's mineral industry, and an outlook section.

The USGS continually strives to improve the value of its publications to users. Constructive comments and suggestions by readers of the Minerals Yearbook are welcomed.

Mark D. Myers, Director

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Contacts

Information about the U.S. Geological Survey, its programs, staff, and products may be accessed on the World Wide Web at URL http://www.usgs.gov or by contacting the Earth Science Information Center at 1-888-ASK-USGS. For specific information about this publication, contact the Acting Chief, Industrial Minerals Section, or the Chief, Metals Section, at (703) 648-4976; or the Team Secretary at (703) 648-4961. Additional minerals information may be accessed on the World Wide Web at URL http://minerals.usgs.gov/minerals.

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Acknowledgments

Volume I, Metals and Minerals, of the Minerals Yearbook presents data on more than 80 minerals and materials that were collected as a result of the information gathering activities of the U.S. Geological Survey.

The collection, compilation, and analysis of domestic mineral industry data were performed by the staff of the Minerals Information Team. Statistical data were compiled from information supplied by mineral producers and consumers in response to canvasses, and their responses are greatfully appreciated. Information obtained from individual firms by means of the U.S. Geological Survey canvasses has been grouped to provide statistical aggregates. Data on individual firms are presented only if available from published or other nonproprietary sources or when permission of the respondent has been granted. The chapters on "Survey Methods of Nonfuel Minerals" and "Statistical Summary" discuss in greater detail procedures for canvassing the mineral industry and the processing and evaluation of these data. Other information appearing in this volume was obtained from the trade and technical press, industry contacts, and additional sources; this cooperation is gratefully acknowledged.

Statistics on world production were compiled from numerous sources, including reports from the U.S. Department of State. U.S. foreign trade data were obtained from reports of the U.S. Department of Commerce, U.S. Census Bureau. The U.S. Geological Survey also was assisted by numerous cooperating State agencies.

John H. DeYoung, Jr.
Chief Scientist, Minerals Information Team

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Survey Methods for Nonfuel Minerals

By Jeffrey P. Busse

The U.S. Geological Survey (USGS) collects worldwide data on virtually every commercially important nonfuel mineral commodity. These data form the basis for tracking and assessing the health of the minerals sector of the U.S. economy.

The USGS data collection activity was instituted by the 47th Congress in the appropriations act of August 7, 1882 (22 Stat. 329), which placed the collection of mineral statistics on an annual basis. The most recent authority for the USGS survey activity is the National Materials and Minerals Policy, Research and Development Act of 1980 (Public Law 96-479, 94 Stat. 2305). The Act included provisions to strengthen protection for proprietary data provided to the U.S. Department of the Interior by persons or firms engaged in any phase of mineral or mineral-material production or consumption.

Data Collection Surveys

The USGS begins the collection of domestic nonfuel minerals and materials statistics by appraising the information requirements of Government and private organizations of the United States. Requirements that can be met by collecting data from minerals establishments are posed as questions on USGS surveys. Figure 1 shows a typical survey form.

Specific questions about mineral commodity activities, such as production, consumption, and shipments, are structured in the survey forms to provide meaningful aggregated data. Thus, the entire mineral economic cycle from production through consumption is covered by 140 monthly, quarterly, semiannual, and annual surveys.

After the survey form has been designed, a list of the appropriate establishments to be canvassed is developed. Many sources are used to determine which companies, mines, plants, and other operations are expected to be included on the survey mailing list. State geologists, Federal organizations (such as the Mine Safety and Health Administration), trade associations, industry representatives, and trade publications and directories are some of the sources that are used to develop and update survey listings. With few exceptions, a complete canvass of the list of establishments is used rather than a sample survey. The iron and steel scrap and pig iron canvass is one of the exceptions where a sample survey is conducted.

The Paperwork Reduction Act requires that any Government agency that wants to collect information from 10 or more individuals or establishments must first obtain approval from the Office of Management and Budget (OMB), which approves the need to collect the data and protects industry from unwarranted Government paperwork. This approval is indicated by the OMB Control Number on the survey forms (figure 1).

Survey Processing

The USGS surveys approximately 20,000 establishments. Each year, the USGS mails about 34,000 forms for 140 different surveys. Each completed survey form returned to the USGS undergoes extensive analysis, including computerized checks, to ensure the highest possible accuracy of the mineral data. The statistical staff monitors all surveys to ensure that errors are not created by reporting in physical units different from the units requested on the form. Relations between associated measures, such as produced crude ore and marketable crude ore, are analyzed for consistency. Engineering variables, such as recovery factors from ores and concentrates, also are used. The totals for each form are verified, and currently reported data are checked against prior reports to detect possible errors or omissions.

The USGS is also developing an Internet-based electronic forms system as required by the Government Paperwork Elimination Act (GPEA). This electronic system is designed to speed the collection and analysis of minerals information. As of December 2005, 25 canvass forms, accounting for 81% of annual responses covered by GPEA, are available electronically.

Survey Responses.—To enable the reader to better understand the basis on which the statistics are calculated, each mineral commodity chapter includes a section about domestic data coverage. This section briefly describes the data sources, the number of establishments surveyed, the response percentage, and the method of estimating the production or consumption for nonrespondents.

To produce reliable aggregated data, the USGS uses efficient procedures for handling instances of nonresponse. Failure to respond to the initial survey form results in a second request, either a second mailing of the paper form or an e-mail in the case of electronic respondents. If the second request does not produce a response, then telephone calls are made to the nonrespondents. The followup calls provide the necessary data to complete the survey forms and/or to verify questionable data entries. Periodic visits to mineral establishments also are made by USGS mineral commodity specialists to gather missing data and to explain the importance of the establishment's reporting. By describing the use of the published statistics and showing the impact of nonresponse, the USGS strives to encourage respondents to give complete and accurate replies.

The OMB publication "Guidelines for Reducing Reporting Burden" stipulates that the minimum acceptable response rate is 75% of the panel surveyed. In addition, the USGS strives for a minimum reporting level of 75% of the quantity produced or consumed (depending on the survey) for certain key statistics. Response rates are periodically reviewed. For those surveys that do not meet the minimum reporting level, procedures are developed and implemented to improve response rates.

Estimation for Nonresponse.—When efforts to obtain a response to a survey fail, estimation or imputation techniques must be used to account for missing data. Some of the estimation methods depend on knowledge of prior establishment reporting; other techniques rely on external information to estimate the missing data. When survey forms are received

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after the current publication has been completed, the forms are reviewed, necessary imputations are made for missing data, and the survey database is updated. The revised data are reported in later publications.

Protection of Proprietary Data.—The USGS relies on the cooperation of the U.S. minerals industry to provide the mineral data that are presented in this and other USGS minerals information publications. Without a strong response to survey requests, the USGS would not be able to present reliable statistics. The USGS, in turn, respects the proprietary nature of the data received from the individual companies and establishments. To ensure that proprietary rights will not be violated, the USGS analyzes each of the aggregated statistics to determine if the data reported by an individual establishment can be deduced from the aggregated statistics. If, for example, there are only two significant producers of a mineral commodity in a given State, then the USGS will not publish the State total because either producer could readily estimate the production of the other. It is this obligation to protect proprietary information that results in the withheld, or W, entries in the published tables. If a company gives permission in writing, however, then the USGS will publish the data as long as the data from other respondents are protected from disclosure.

International Data

International data are collected by USGS country specialists and international data coordinators. The data are gathered from various sources, which include published reports of foreign Government mineral and statistical agencies, international organizations, the U.S. Department of State, the United Nations, the Organization of the Petroleum Exporting Countries, and personal contact by specialists traveling abroad. Each February, minerals questionnaires are sent to foreign organizations requesting estimates of mineral production for the country for the preceding year. Missing data are estimated by USGS country specialists on the basis of historical trends and the specialist's knowledge of current production capabilities in each country.

Publications

The USGS disseminates current and historical minerals information through printed publications and its Web site.

Printed Publications.—The Minerals Yearbook summarizes annually, on a calendar-year basis, the significant economic and technical developments in the mineral industries. Three volumes are issued each year—volume I, Metals and Minerals; volume II, Area Reports: Domestic; and volume III, Area Reports: International. Volume I presents, by mineral commodity, salient statistics on production, trade, consumption, reserves, and other measures of economic activity. Volume II reviews the U.S. minerals industry by State and island possessions. Volume III is published as four separate regional reports that cover more than 175 foreign countries. These reports contain individual country chapters that examine the mining, refining, processing, and use of minerals in each country in the region and how they relate to U.S. industry.

The Mineral Commodity Summaries (MCS), which is an up-to-date summary of about 80 nonfuel mineral commodities, is the earliest Government publication to furnish estimates that cover the previous year's nonfuel mineral industry data. It contains information on the domestic industry structure, Government programs, tariffs, 5-year salient domestic statistics, and a summary of significant events, trends, and issues in the international minerals industry during the past year.

The Minerals Yearbook and the MCS may be purchased from the U.S. Government Printing Office, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250; telephone, (202) 512-1800 or (866) 512-1800 (toll-free); Internet, http://bookstore.gpo.gov.

Electronic Publications.—Current and historical minerals information is available through the USGS Web site at URL http://minerals.usgs.gov/minerals. The Web site provides USGS minerals information products to view or download, as well as USGS contacts for minerals information and links to other mineral-related sites on the Internet.

Mineral Industry Surveys (MIS) contain timely statistical and economic data on minerals. The surveys are designed to keep Government agencies and the public, particularly the mineral industry and the business community, informed of trends in the production, distribution, inventories, and consumption of minerals. Frequency of issue depends on the demand for current data. MIS are released monthly, quarterly, semiannually, or annually.

Metal Industry Indicators, which is published monthly, contains indexes that measure the current and future performance of three U.S. metal industries. For each of the three industries, a composite coincident index and a composite leading index have been developed based on procedures and data similar to those used to construct the Conference Board's coincident and leading cyclical indexes for the national economy. Nonmetallic Mineral Products Industry Indexes, also published monthly, contains leading and coincident indexes which measure the current and future performance of the industrial minerals industry. The indexes were designed by using the same procedures as the USGS metal composite indexes.

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FIGURE 1
A TYPICAL SURVEY FORM

USGS Form 9-4045-M
Fer. (rev. 2/18/2005)

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Approval expires: 1/31/2008

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A03

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DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
986 NATIONAL CENTER
RESTON, VIRGINIA 20192

IRON ORE (Usable ore)

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Collection of nonfuel minerals information is authorized by Public Law 96-479 and the Defense Production Act. This information is used to support executive policy decisions pertaining to emergency preparedness, national defense, and analyses for minerals legislation and industrial trends. The USGS relies on your voluntary and timely response to assure that its information is complete and accurate.

Please return this form in the enclosed envelope or fax to the above toll-free number by the **15TH OF THE MONTH** following the reporting period. Complete a separate form for each mineral establishment that was active during the reporting period. A minerals establishment is defined as a single physical location where mineral operations are conducted; for example, a mine only, a mine and preparation plant, or a preparation plant only. If you do not have exact data, please enter your best estimates and mark with an /e. Use zero (0) when appropriate. Do not report decimals or fractions. Round to the nearest whole number. If you have nothing to report, please complete Section 1, sign, and return the form. Please use the space for "Remarks" to provide any specific information that will help us in the use or interpretation of the data. Any statement on the effect of changes in economic conditions upon the reporting establishment will be useful. Additional forms are available upon request.

If you have any questions concerning completion of this form, please contact the Mineral Commodities Data Unit, U.S. Geological Survey, 985 National Center, Reston, VA 20192, Telephone (703) 648-7960.

SECTION 1. Mine or group covered by this report.

Name _____ State _____ County _____

SECTION 2. Stocks, production, and shipments of usable ore for the report month.
Report only ore products as shipped to consumer, such as direct-shipping ore, concentrate, or agglomerates.
Report ores produced in the United States only; do not include imports.

Usable ore (1)	Code	Weight unit Mark (X) one (2) Long tons (4)	Weight unit Mark (X) one (2) Metric tons (6)	Physical inventory Adjustment only (3)	Beginning stocks (4)	Production (5)	Shipments (6)	Ending stocks (7)
Iron ore (containing less that 5% Mn, natural.....	201							

SECTION 3. Please indicate any mines opened or closed by your company during the month.

Remarks:

Name of person to be contacted regarding this report			Tel. area code	No.	Ext.
Address	No.	Street	City	State	ZIP Code

May tabulations be published which could indirectly reveal the data reported above? ☐ (1) Yes ☐ (2) No

Signature	Title	Date

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Statistical Summary

By Stephen D. Smith and Christopher H. Lindsay

This annual report summarizes data on crude nonfuel mineral production[1] for the United States, its island possessions, and the Commonwealth of Puerto Rico.

Although crude mineral production may be measured at any of several stages of extraction and processing, the stage of measurement used in this annual report is what is termed "mine output." This term refers to minerals or ores in the form in which they are first extracted from the ground, but customarily may include the output from auxiliary processing at or near the mines.

Because of inadequacies in the statistics available, some series deviate from the foregoing definition. For copper, gold, lead, silver, and zinc, the quantities listed are recorded on a mine basis (as the recoverable content of ore sold or treated). The values assigned to the quantities, however, are based on the average selling price of refined metal, not the mine value.

The total value of all nonfuel mineral production in the United States in 2005 increased to $55.2 billion, which was an increase of almost 22% compared with that of 2004; metals increased to $16.5 billion, which was an increase of more than 32%; and industrial minerals increased to $38.7 billion, more than 17%.

In 2005, the value of nonfuel mineral commodity production for the following 11 commodities, in descending order of production value, was greater than $1 billion: stone (crushed), cement (portland), sand and gravel (construction), copper, gold, molybdenum concentrates, iron ore (usable shipped), lime, salt, phosphate rock, and zinc. They accounted for more than 85% of the U.S. total production value (table 1).

In 2005, the value of nonfuel mineral commodity production in the following 20 States, in descending order of production value, was greater than $1 billion: Arizona, California, Nevada, Florida, Utah, Texas, Minnesota, Missouri, Georgia, Colorado, Michigan, Pennsylvania, Alaska, Wyoming, New York, Illinois, Ohio, Virginia, New Mexico, and Alabama. They accounted for more than 75% of the U.S. total production value (table 3).

[1]The terms "nonfuel mineral production" and related "values" encompass variations in meaning, depending upon the mineral products. Production may be measured by mine shipments, mineral commodity sales, or marketable production (including consumption by producers) as is applicable to the individual mineral commodity.

All 2005 U.S. Geological Survey (USGS) mineral production data published in this chapter are as of March 2007. For some mineral commodities, such as construction sand and gravel, crushed stone, and portland cement, estimates are updated periodically. To obtain the most current information, please contact the appropriate USGS mineral commodity specialist. Specialist contact information are available on the Internet at http://minerals.usgs.gov/minerals/contacts/comdir.html; alternatively, specialists' names and telephone numbers may be obtained by calling USGS information at (703) 648-4000 or by calling the USGS Earth Science Information Center at 1-888-ASK-USGS (275-8747). All Mineral Industry Surveys—mineral commodity, State, and country—are also available on the Internet at http://minerals.usgs.gov/minerals.

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TABLE 1
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		2003		2004		2005	
		Quantity	Value	Quantity	Value	Quantity	Value
Metals:							
Beryllium concentrates	metric tons	2,100	NA	2,210	NA	2,780	NA
Copper[3]		1,120	2,100,000	1,160	3,420,000	1,140	4,360,000
Gold[3]	kilograms	277,000	3,250,000	258,000	3,400,000	256,000	3,670,000
Iron ore, usable shipped		46,100	1,490,000	54,900	2,080,000	53,200	2,370,000
Iron oxide pigments, crude	metric tons	50,900	814	(4)	W	(4)	795
Lead[3]	do.	449,000	433,000	430,000	523,000	426,000	574,000
Molybdenum concentrates[5, 6]	do.	33,600	324,000	42,000	1,420,000	58,000	3,660,000
Palladium[5]	kilograms	14,000	91,400	13,700	102,000	13,300	87,100
Platinum[5]	do.	4,170	93,100	4,040	110,000	3,920	113,000
Silver[3]	do.	1,240,000	196,000	1,250,000	268,000	1,230,000	289,000
Zinc[3]	metric tons	738,000	661,000	715,000	827,000	720,000	1,070,000
Combined value of cadmium byproduct in zinc concentrates, magnesium metal, titanium concentrates, zirconium concentrates, and value indicated by symbol W		XX	233,000	XX	304,000	XX	316,000
Total		XX	8,870,000	XX	12,500,000	XX	16,500,000
Industrial minerals, excluding fuels:							
Barite		468	13,900	532	18,700	489	17,600
Boron		1,150	591,000	1,210	626,000	1,150	713,000
Bromine	metric tons	216,000	155,000	222,000	191,000	226,000	168,000
Cement:							
Masonry		4,740	468,000 e	5,000	585,000 e	5,420	679,000 e
Portland		88,100	6,460,000 e	92,400	7,110,000 e	93,900	8,360,000 e
Clays:							
Ball		1,310	56,200	1,220	54,100	1,210	52,900
Bentonite		3,940	177,000	4,060	179,000	4,710	215,000
Common		23,100	131,000	24,600	157,000	24,300	176,000
Fire		400	10,200	256	7,870	353	10,700
Fuller's earth[7]		3,610	332,000	3,260	329,000	2,990	339,000
Kaolin		7,680	939,000	7,760	945,000	7,800	860,000
Diatomite		599	159,000	620	177,000	653	179,000
Feldspar		800	43,400	770	44,200	750	43,000
Garnet, industrial	metric tons	29,200	3,170	28,400	3,050	440,000	3,840
Gemstones, natural		NA	12,500	NA	14,500	NA	13,400
Gypsum, crude		16,700	114,000	17,200	124,000	21,100	158,000
Helium:							
Crude	million cubic meters	49	67,000	57	77,500	42	63,300
Grade-A	do.	122	282,000	130	299,000	133	336,000
Iodine	metric tons	1,090	15,900	1,130	W	1,570	W
Kyanite[e]		90	13,400	90	13,400	90	13,400
Lime		(4)	W	20,000	1,370,000	20,000	1,500,000
Mica, crude		79	16,700	99,200	15,400	78,100	19,600
Peat[8]		632	18,800	741 r	21,200	751	20,800
Perlite, crude	metric tons	493,000	18,800	508,000	20,600	508,000	20,700
Phosphate rock, marketable		35,000	946,000	35,800	995,000	36,100	1,070,000
Potash		2,500	280,000	2,700	340,000	2,500	410,000
Pumice and pumicite	metric tons	870,000	21,900	1,490,000	25,000	1,270,000	39,300
Salt		41,100	1,130,000	45,000	1,270,000	45,000	1,310,000
Sand and gravel:							
Construction		1,160,000	5,990,000	1,240,000	6,590,000	1,270,000	7,460,000
Industrial		27,500	609,000	29,700	685,000	30,600	752,000
Silica stone[9]	metric tons	513	3,630	655	3,660	576	2,290
Soda ash		10,600	765,000	11,000	770,000	11,000	968,000
Stone, crushed[10]		1,530,000	9,060,000	1,440,000 r	9,320,000 r	1,690,000	12,100,000
Tripoli	metric tons	68,800	17,700	94,000	19,400	91,100	18,700
Zeolites	do.	(4)	NA	(4)	W	(4)	W

See footnotes at end of table.

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TABLE 1—Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	2003		2004		2005	
	Quantity	Value	Quantity	Value	Quantity	Value
Industrial minerals, excluding fuels—Continued:						
Combined value of brucite, greensand marl, lithium carbonate, magnesite, magnesium compounds, olivine, pyrophyllite (crude), staurolite, stone (dimension), talc (crude), vermiculite (crude), wollastonite, and values indicated by symbol W	XX	1,800,000	XX	531,000	XX	555,000
Total	XX	30,700,000	XX	32,900,000 r	XX	38,700,000
Grand total	XX	39,600,000	XX	45,400,000 r	XX	55,200,000

[e]Estimated. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; value included with "Combined value.'
XX Not applicable.
[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producers)
[2]Data are rounded to three significant digits; may not add to totals shown.
[3]Recoverable content of ores, etc.
[4]Withheld to avoid disclosing company proprietary data.
[5]Content of ore and concentrate.
[6]Shipments.
[7]Sales.
[8]Excludes attapulgite.
[9]Includes grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.
[10]Excludes abrasive stone and bituminous limestone and sandstone; all included elsewhere in table.

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TABLE 2
NONFUEL MINERALS PRODUCED IN THE UNITED STATES, BY COMMODITY AND STATES IN 2005

(Principal States based on quantity unless otherwise noted)

Mineral	Principal States	Other States (alphabetical order)
Barite	NV and GA	
Beryllium concentrates	UT	
Boron	CA	
Bromine	AR and MI	
Brucite	TX	
Cadmium byproduct in zinc concentrates	AK, WA, MO, MT, ID	
Cement:		
Masonry	FL, CA, SC, AL, IN	AR, AZ, CO, GA, IA, KS, KY, MD, MI, MO, MT, NE, NM, NY, OH, OK, PA, TN, TX, VA, WV.
Portland	CA, TX, PA, FL, MI	All other States, except AK, CT, DE, HI, LA, MA, MN, NH, NJ, NC, ND, RI, VT.
Clays:		
Ball	TN, TX, MS, KY, IN	
Bentonite	WY, MS, MT, AL, UT	AZ, CA, CO, NV, OR, TX, VA.
Common	TX, AL, NC, GA, OH	All other States, except AK, DE, HI, ID, NV, NH, RI, VT, WI.
Fire	MO, OH, SC	
Fuller's earth	GA, MO, MS, VA, FL	CA, IL, KS, NV, TN, TX.
Kaolin	GA, SC, AL, AR, CA	FL, NV, NC, TN, TX.
Copper[1]	AZ, UT, NM, NV, MT	ID and MO.
Diatomite	CA, NV, OR, WA	
Feldspar	NC, VA, CA, OK, GA	ID and SD.
Garnet, industrial	NY, ID, MT	
Gemstones, natural[2]	TN, AZ, OR, CA, AR	All other States.
Gold[1]	NV, UT, AK, CO, MT	AZ, CA, ID, MT, NM, SD, WA.
Greensand marl	NJ	
Gypsum, crude	OK, IA, NV, NY, CA	AR, AZ, CO, IN, KS, LA, MI, NM, SD, TX, UT, WY.
Helium:		
Crude	KS and TX	
Grade-A	KS, WY, OK, CO, UT	TX.
Iodine, crude	OK	
Iron ore, usable	MN, MI, CA	
Iron oxide pigments, crude	GA, MI, AL, VA	
Kyanite	VA	
Lead[1]	MO, AK, ID, WA, MT	
Lime	MO, KY, AL, OH, TX	All other States, except AK, CT, DE, HI, KS, ME, MD, MS, NH, NJ, NY, NC, RI, SC, VT.
Lithium carbonate	NV	
Magnesite	NV	
Magnesium compounds	MI, UT, FL, DE, CA	
Magnesium metal	UT	
Mica, crude	NC, AL, SD, SC, GA	
Molybdenum, concentrates	UT, CO, AZ, ID, MT	NM.
Olivine	WA and NC	
Palladium[1]	MT	
Peat	FL, MI, MN, IL, IN	IA, ME, MT, NJ, NY, OH, PA, WA, WV, WI.
Perlite, crude	NM, OR, AZ, UT, CA	ID and NV.
Phosphate rock	FL, NC, ID, UT	
Platinum[1]	MT	
Potash	NM, UT, MI	
Pumice and pumicite	AZ, OR, CA, NM, ID	KS.
Pyrophyllite, crude	NC	
Salt	LA, TX, NY, OH, KS	AL, AZ, CA, MI, NV, NM, OK, TN, UT, WV.
Sand and gravel:		
Construction	CA, AZ, TX, MI, MN	All other States.
Industrial	IL, TX, WI, CA, NJ	All other States, except AK, CT, DE, HI, KY, ME, MA, MT, NE, NH, NY, OR, SD, UT, VT, WY.
Silica stone[3]	AR	
Silver[1]	AK, NV, ID, UT, MT	AZ, CA, CO, MO, NM, WA.
Soda ash	WY and CA	
Staurolite	FL	

See footnotes at end of table.

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TABLE 2—Continued
NONFUEL MINERALS PRODUCED IN THE UNITED STATES, BY COMMODITY AND STATES IN 2005

(Principal States based upon quantity unless otherwise noted)

Mineral	Principal States	Other States (alphabetical order)
Stone:		
Crushed	TX, FL, PA, MO, VA	All other States, except DE.
Dimension	WI, GA, IN, VT, MA	All other States, except AK, DE, FL, HI, IA, KY, LA, MS, NE, NV, NJ, ND, OR, RI, WY.
Talc, crude	MT, TX, VT, NY, VA	OR.
Titanium concentrates:		
Ilmenite	FL, VA, GA	
Rutile	FL	
Tripoli	IL, OK, AR, PA	
Vermiculite, crude	SC and VA	
Wollastonite	NY	
Zeolites	NM, ID, TX, AZ, NV	CA and WY.
Zinc[1]	AK, WA, MO, MT, ID	
Zirconium concentrates	FL, VA, GA	

[1]Content of ores, etc.
[2]Principal producing States based on value.
[3]Grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.

TABLE 3
VALUE OF NONFUEL MINERAL PRODUCTION IN THE UNITED STATES AND PRINCIPAL NONFUEL MINERALS PRODUCED IN 2005[1]

State	Value (thousands)	Rank	Percentage of U.S. total	Principal minerals, in order of value
Alabama	$1,120,000	20	2.03	Cement (portland), stone (crushed), lime, sand and gravel (construction), cement (masonry).
Alaska	1,470,000	13	2.66	Zinc, lead, gold, silver, sand and gravel (construction).
Arizona	4,350,000	1	7.88	Copper, molybdenum concentrates, sand and gravel (construction), cement (portland), stone (crushed).
Arkansas	591,000	32	1.07	Stone (crushed), bromine, cement (portland), sand and gravel (construction), lime.
California	4,240,000	2	7.68	Sand and gravel (construction), cement (portland), boron minerals, stone (crushed), soda ash.
Colorado	1,750,000	10	3.17	Molybdenum concentrates, sand and gravel (construction), cement (portland), gold, stone (crushed).
Connecticut[2]	157,000	42	0.28	Stone (crushed), sand and gravel (construction), stone (dimension), clays (common), gemstones (natural).
Delaware[2]	20,000	50	0.04	Sand and gravel (construction), magnesium compounds, stone (crushed), gemstones (natural).
Florida	2,890,000	4	5.24	Stone (crushed), phosphate rock, cement (portland), sand and gravel (construction), cement (masonry).
Georgia	1,810,000	9	3.28	Clays (kaolin), stone (crushed), clays (fuller's earth), sand and gravel (construction), cement (portland).
Hawaii	100,000	45	0.18	Stone (crushed), sand and gravel (construction), gemstones (natural).
Idaho	906,000	21	1.64	Molybdenum (concentrates), phosphate rock, sand and gravel (construction), silver, cement (portland).
Illinois	1,210,000	16	2.19	Stone (crushed), cement (portland), sand and gravel (construction), sand and gravel (industrial), clays (fuller's earth).
Indiana	883,000	22	1.60	Stone (crushed), cement (portland), sand and gravel (construction), lime, cement (masonry).
Iowa	641,000	29	1.16	Cement (portland), stone (crushed), sand and gravel (construction), gypsum (crude), lime.
Kansas	870,000	23	1.58	Cement (portland), helium (Grade-A), stone (crushed), salt, helium (crude).
Kentucky	765,000	27	1.39	Stone (crushed), lime, cement (portland), sand and gravel (construction), stone (crushed).
Louisiana	393,000	36	0.71	Salt, sand and gravel (construction), stone (crushed), clays (common), sand and gravel (industrial).
Maine	141,000	43	0.26	Sand and gravel (construction), cement (portland), stone (crushed), stone (dimension), peat.
Maryland[2]	577,000	33	1.05	Stone (crushed), cement (portland), sand and gravel (construction), cement (masonry), stone (dimension).
Massachusetts[2]	250,000	38	0.45	Stone (crushed), sand and gravel (construction), lime, stone (dimension), clays (common).
Michigan	1,750,000	11	3.17	Iron ore (usable shipped), cement (portland), sand and gravel (construction), stone (crushed), salt
Minnesota[2]	2,190,000	7	3.97	Iron ore (usable shipped), sand and gravel (construction), stone (crushed), sand and gravel (industrial), stone (dimension).
Mississippi	215,000	40	0.39	Sand and gravel (construction), stone (crushed), cement (portland), clays (fuller's earth), clays (bentonite).
Missouri	1,940,000	8	3.51	Stone (crushed), cement (portland), lead, lime, sand and gravel (construction).
Montana	847,000	24	1.53	Molybdenum (concentrates), copper, platinum metal, palladium metal, sand and gravel (construction).
Nebraska[2]	110,000	44	0.20	Cement (portland), sand and gravel (construction), stone (crushed), lime, clays (common).
Nevada	3,880,000	3	7.03	Gold, sand and gravel (construction), copper, lime, stone (crushed).
New Hampshire[2]	88,200	47	0.16	Sand and gravel (construction), stone (crushed), stone (dimension), gemstones (natural).

See footnotes at end of table.

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TABLE 3—Continued

VALUE OF NONFUEL MINERAL PRODUCTION IN THE UNITED STATES AND PRINCIPAL NONFUEL MINERALS PRODUCED IN 2005[1]

State	Value (thousands)	Rank	Percentage of U.S. total	Principal minerals, in order of value
New Jersey[2]	344,000	37	0.62	Stone (crushed), sand and gravel (construction), sand and gravel (industrial), greensand marl, peat.
New Mexico	1,150,000	19	2.08	Copper, potash, molybdenum (concentrates), sand and gravel (construction), cement (portland).
New York	1,290,000	15	2.34	Stone (crushed), salt, cement (portland), sand and gravel (construction), wollastonite.
North Carolina[2]	792,000	25	1.43	Stone (crushed), phosphate rock, sand and gravel (construction), sand and gravel (industrial), feldspar.
North Dakota	45,600	48	0.08	Sand and gravel (construction), lime, stone (crushed), clays (common), sand and gravel (industrial).
Ohio	1,210,000	17	2.19	Stone (crushed), sand and gravel (construction), salt, lime, cement (portland).
Oklahoma	606,000	31	1.10	Stone (crushed), cement (portland), sand and gravel (construction), sand and gravel (industrial), iodine (crude).
Oregon	432,000	35	0.78	Stone (crushed), sand and gravel (construction), cement (portland), diatomite, lime.
Pennsylvania[2]	1,550,000	12	2.81	Stone (crushed), cement (portland), sand and gravel (construction), lime, cement (masonry).
Rhode Island[2]	35,400	49	0.06	Sand and gravel (construction), stone (crushed), sand and gravel (industrial), gemstones (natural).
South Carolina	659,000	28	1.19	Stone (crushed), cement (portland), cement (masonry), sand and gravel (construction), sand and gravel (industrial).
South Dakota	215,000	39	0.39	Cement (portland), sand and gravel (construction), stone (crushed), gold, stone (dimension).
Tennessee	770,000	26	1.39	Stone (crushed), cement (portland), sand and gravel (construction), clays (ball), sand and gravel (industrial).
Texas	2,720,000	6	4.93	Cement (portland), stone (crushed), sand and gravel (construction), salt, sand and gravel (industrial).
Utah	2,790,000	5	5.05	Molybdenum (concentrates), copper, gold, cement (portland), sand and gravel (construction).
Vermont[2]	96,800	46	0.18	Stone (crushed), sand and gravel (construction), stone (dimension), talc (crude), gemstones (natural).
Virginia	1,160,000	18	2.10	Stone (crushed), cement (portland), sand and gravel (construction), lime, zirconium (concentrates).
Washington	633,000	30	1.15	Sand and gravel (construction), stone (crushed), cement (portland), zinc, gold.
West Virginia	200,000	41	0.36	Stone (crushed), cement (portland), sand and gravel (industrial), lime, cement (masonry).
Wisconsin[2]	562,000	34	1.02	Stone (crushed), sand and gravel (construction), lime, sand and gravel (industrial), stone (dimension).
Wyoming	1,300,000	14	2.36	Soda ash, clays (bentonite), helium (Grade-A), sand and gravel (construction), cement (portland).
Undistributed	431,000	XX	0.78	
Total	55,200,000	XX	100.00	

XX Not applicable.

[1]Data are rounded to three significant digits; may not add to totals shown.

[2]Partial total; excludes values that must be withheld to avoid disclosing company proprietary data which are included with "Undistributed."

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TABLE 4

VALUE OF NONFUEL MINERAL PRODUCTION PER CAPITA AND PER SQUARE KILOMETER IN 2005 BY STATE[1]

State	Area (square kilometers)	Population (thousands)	Total value (thousands)	Per capita		Per square kilometer	
				Dollars	Rank	Dollars	Rank
Alabama	134,000	4,560	$1,120,000	$246	14	$8,390	20
Alaska	1,530,000	664	1,470,000	2,220	2	961	48
Arizona	295,000	5,940	4,350,000	732	6	14,700	4
Arkansas	138,000	2,780	591,000	213	16	4,290	30
California	411,000	36,100	4,240,000	117	30	10,300	16
Colorado	270,000	4,670	1,750,000	376	10	6,500	25
Connecticut	13,000	3,510	157,000 [2]	45	46	12,100	8
Delaware	5,290	844	20,000 [2]	24	50	3,780	36
Florida	152,000	17,800	2,890,000	162	21	19,000	2
Georgia	153,000	9,070	1,810,000	199	17	11,800	9
Hawaii	16,800	1,280	100,000	78	40	5,970	26
Idaho	216,000	1,430	906,000	634	7	4,190	31
Illinois	146,000	12,800	1,210,000	95	37	8,300	21
Indiana	93,700	6,270	883,000	141	25	9,420	19
Iowa	146,000	2,970	641,000	216	15	4,400	29
Kansas	213,000	2,750	870,000	317	12	4,080	32
Kentucky	105,000	4,170	765,000	183	18	7,310	23
Louisiana	124,000	4,520	393,000	87	39	3,180	42
Maine	86,200	1,320	141,000	107	32	1,630	46
Maryland	27,100	5,600	577,000 [2]	103	34	21,300	1
Massachusetts	21,500	6,400	250,000 [2]	39	48	11,700	10
Michigan	152,000	10,100	1,750,000	173	19	11,500	11
Minnesota	219,000	5,130	2,190,000 [2]	427	9	10,000	18
Mississippi	124,000	2,920	215,000	73	41	1,740	44
Missouri	181,000	5,800	1,940,000	335	11	10,800	15
Montana	381,000	936	847,000	906	5	2,230	43
Nebraska	200,000	1,760	110,000 [2]	63	45	550	49
Nevada	286,000	2,420	3,880,000	1,610	3	13,600	5
New Hampshire	24,000	1,310	88,200 [2]	67	43	3,670	37
New Jersey	20,200	8,720	344,000 [2]	39	47	17,000	3
New Mexico	315,000	1,930	1,150,000	596	8	3,650	38
New York	127,000	19,300	1,290,000	67	44	10,200	17
North Carolina	136,000	8,680	792,000 [2]	91	38	5,810	27
North Dakota	183,000	637	45,600	72	42	249	50
Ohio	107,000	11,500	1,210,000	105	33	11,300	13
Oklahoma	181,000	3,550	606,000	171	20	3,350	40
Oregon	251,000	3,640	432,000	119	29	1,720	45
Pennsylvania	117,000	12,400	1,550,000 [2]	125	27	13,200	6
Rhode Island	3,140	1,080	35,400 [2]	33	49	11,300	12
South Carolina	80,600	4,260	659,000	155	23	8,180	22
South Dakota	200,000	776	215,000	277	13	1,080	47
Tennessee	109,000	5,960	770,000	129	26	7,060	24
Texas	691,000	22,900	2,720,000	119	28	3,940	33
Utah	220,000	2,470	2,790,000	1,130	4	12,700	7
Vermont	24,900	623	96,800 [2]	155	22	3,890	34
Virginia	106,000	7,570	1,160,000	153	24	10,900	14
Washington	176,000	6,290	633,000	101	36	3,590	39
West Virginia	62,800	1,820	200,000	110	31	3,200	41
Wisconsin	145,000	5,540	562,000 [2]	102	35	3,870	35
Wyoming	253,000	509	1,300,000	2,550	1	5,130	28
Undistributed	XX	XX	431,000	XX	XX	XX	XX
Total or average	9,370,000 [3]	296,000 [3]	55,200,000	186	XX	5,890	XX

XX Not applicable.

[1]Data are rounded to three significant digits; may not add to totals shown.

[2]Partial total; excludes values that must be withheld to avoid disclosing company proprietary data. Withheld values included with "Undistributed."

[3]Excludes Washington, DC (which has no mineral production), with an area of 179 square kilometers and a population of 551,000.

Sources: U.S. Geological Survey and U.S. Census Bureau.

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TABLE 5
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	2003 Quantity	2003 Value	2004 Quantity	2004 Value	2005 Quantity	2005 Value
Alabama:						
Cement:						
Masonry	565	55,700 e	430	49,400 e	475	54,800 e
Portland	4,330	273,000 e	4,800	320,000 e	5,120	421,000 e
Clays:						
Bentonite	125	3,810	100	3,050	109	3,480
Common	1,920	24,000	2,120	29,600	2,280	29,000
Gemstones	NA	356	NA	356	NA	371
Lime	2,290	151,000	2,280	164,000	2,240	181,000
Sand and gravel:						
Construction	14,500	67,600	14,700	65,300	15,700	70,500
Industrial	723	9,180	643	9,800	710	11,200
Stone, crushed	49,300	286,000	47,800 r	296,000 r	49,500	325,000
Combined values of clays (kaolin), iron oxide pigments (crude), mica [crude (2004)], salt, stone (dimension marble and sandstone)	XX	30,000	XX	27,000	XX	27,000
Total	XX	900,000	XX	965,000 r	XX	1,120,000
Alaska:						
Gemstones	NA	12	NA	12	NA	12
Sand and gravel, construction	9,980	55,700	9,430	51,600	8,660	48,100
Stone, crushed	2,640 3	15,300 3	2,270 r	14,200 r	2,360	15,600
Combined values of cadmium [byproduct of zinc concentrates (2004-05)], gold, lead, silver, stone [crushed granite and shell (2003-04)], zinc	XX	1,010,000	XX	1,200,000	XX	1,410,000
Total	XX	1,080,000	XX	1,270,000	XX	1,470,000
Arizona:						
Copper[4]	741	1,390,000	723	2,130,000	690	2,640,000
Gemstones	NA	1,440	NA	1,450	NA	1,370
Sand and gravel:						
Construction	62,600	340,000	79,600	430,000	84,900	516,000
Industrial	(5)	W	(5)	792	(5)	W
Stone, crushed	9,950	49,100	14,100 r	75,900 r	12,000 3	69,300 3
Combined values of cement, clays (bentonite, common), gold, gypsum (crude), lime, molybdenum concentrates, perlite (crude), pumice and pumicite, salt, silver, stone [crushed traprock (2005), dimension sandstone], zeolites (2004-05), and values indicated by symbol W	XX	394,000	XX	709,000	XX	1,120,000
Total	XX	2,180,000	XX	3,350,000 r	XX	4,350,000
Arkansas:						
Clays, common	897	1,410	1,150	1,510	1,210	1,900
Gemstones	NA	477	NA	590	NA	711
Sand and gravel, construction	9,720	52,100	9,370	53,500	10,600	62,000
Silica stone[6] metric tons	513	3,630	655	3,660	576	2,290
Stone, crushed	29,700	145,000	34,100 r, 3	173,000 r, 3	35,400 3	223,000 3
Combined values of bromine, cement, clays (kaolin), gypsum (crude), lime, sand and gravel (industrial), stone [crushed slate (2004-05), dimension limestone and sandstone], tripoli	XX	252,000	XX	299,000 r	XX	302,000
Total	XX	454,000	XX	531,000 r	XX	591,000
California:						
Boron minerals	1,150	591,000	1,210	626,000	1,150	713,000
Cement:						
Masonry	(5)	W	(5)	W	694	80,600 e
Portland	11,600	887,000 e	11,900	1,000,000 e	11,600	1,130,000 e
Clays:						
Bentonite	23	2,560	24	2,640	20	2,200
Common	1,240	19,100	1,230	20,700	1,010	16,600
Fuller's earth	(5)	W	197	W	189	W

See footnotes at end of table.

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TABLE 5—Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		2003 Quantity	2003 Value	2004 Quantity	2004 Value	2005 Quantity	2005 Value
California—Continued:							
Gemstones		NA	1,080	NA	1,070	NA	1,130
Gold[4]	kilograms	4,270	50,100	3,260	43,000	(5)	W
Sand and gravel:							
Construction		152,000	1,150,000	166,000	1,280,000	163,000	1,440,000
Industrial		1,790	50,100	1,990	55,700	2,030	60,400
Silver[4]	kilograms	957	151	801	172	269	63
Stone:							
Crushed		55,500	371,000	55,300 r, 3	364,000 r, 3	54,300	455,000
Dimension		40	9,920	42	10,200	41	10,200
Combined values of clays (kaolin), diatomite, feldspar, gypsum (crude), iron ore (usable shipped), lime, magnesium compounds, perlite (crude), pumice and pumicite, pyrophyllite [crude (2003)], salt, soda ash, stone [crushed shell (2004)], talc [crude (2004)], zeolites (2004), and values indicated by symbol W		XX	308,000	XX	349,000	XX	332,000
Total		XX	3,440,000	XX	3,760,000	XX	4,240,000
Colorado:							
Clays:							
Bentonite		(5)	W	5	W	3	W
Common		259	1,580	249	1,510	255	1,610
Gemstones		NA	281	NA	360	NA	358
Lime		26	2,330	26	2,570	29	3,900
Sand and gravel:							
Construction		37,500	213,000	40,900	235,000	44,700	280,000
Industrial		70	W	(5)	3,300	(5)	W
Stone:							
Crushed		10,400	64,000	11,100 r	68,300 r	13,000	89,100
Dimension		5	1,610	16	1,980	18	2,400
Combined values of cement, gold, gypsum (crude), helium (Grade-A), molybdenum concentrates, silver, soda ash (2003-04), and values indicated by symbol W		XX	391,000	XX	699,000	XX	1,380,000
Total		XX	673,000	XX	1,010,000	XX	1,750,000
Connecticut							
Clays, common		52	143	87	(6)	89	(6)
Gemstones		NA	6	NA	6	NA	6
Sand and gravel, construction		8,150	51,200	8,330	55,600	8,400	64,200
Stone:							
Crushed		10,400	81,800	10,100 r	75,700	10,100	92,600
Dimension		(5)	(7)	(5)	(7)	(5)	(7)
Total		XX	133 000	XX	131 000	XX	, 157 000
Delaware:							
Gemstones		NA	1	NA	1	NA	1
Magnesium compounds	metric tons	(5)	(7)	(5)	(7)	(5)	(7)
Sand and gravel, construction		2,550	17,900	2,980	21,900	2,640	20,000
Stone, crushed		--	--	--	--	(5)	(7)
Total		XX	17 900	XX	21,900	XX	, 20,000
Florida:							
Cement:							
Masonry		674	82,900 e	763	97,600 e	902	129,000 e
Portland		4,190	323,000 e	5,230	432,000 e	5,730	519,000 e
Clays:							
Common		94 e	1,280 e	(5)	W	(5)	W
Fuller's earth		(5)	W	234	W	279	W
Kaolin		31	3,250	31	3,280	29	3,510
Gemstones		NA	1	NA	1	NA	1
Lime		--	--	24	2,090	23	2,940
Peat		373	7,440	478	9,710	464	9,450

See footnotes at end of table.

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TABLE 5—Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	2003		2004		2005	
	Quantity	Value	Quantity	Value	Quantity	Value
Florida—Continued:						
Sand and gravel:						
Construction	30,900	141,000	29,300	146,000	37,500	210,000
Industrial	624	7,270	679	8,520	715	9,410
Stone, crushed	97,100	587,000	105,000 [3]	680,000 [r, 3]	115,000 [3]	994,000 [3]
Combined values of magnesium compounds, phosphate rock, staurolite, stone [crushed sandstone (2004-05)], titanium concentrates, zirconium concentrates, and values indicated by symbol W	XX	918,000	XX	945,000	XX	1,010,000
Total	XX	2 070,000	XX	2 320,000	XX	2,890,000
Georgia:						
Clays:						
Common	1,280	4,430	1,550	8,710	1,530	8,730
Fuller's earth	1,570	145,000	1,400	142,000	1,410	147,000
Kaolin	6,610	884,000	6,780	898,000	7,190	825,000
Gemstones	NA	8	NA	9	NA	9
Sand and gravel:						
Construction	7,690	31,800	9,270	39,400	11,100	68,300
Industrial	590	11,900	665	13,400	689	15,000
Stone:						
Crushed	75,200	519,000	79,700 [r]	548,000 [r]	79,400	606,000
Dimension	114	22,700	146	22,100	246	21,000
Combined values of barite, cement, feldspar, iron oxide pigments (crude), lime, mica (crude)	XX	117,000	XX	134,000	XX	115,000
Total	XX	1 740,000	XX	1,810,000 [r]	XX	1,810,000
Hawaii:						
Cement, masonry	(5)	(7)	--	--	--	--
Gemstones	NA	119	NA	262	NA	217
Sand and gravel, construction	808	9,560	1,260	12,100	1,390	17,500
Stone, crushed	5,620	65,400	5,470 [r]	61,300 [r]	6,170	82,300
Total	XX	75,100	XX	73,700 [r]	XX	100,000
Idaho:						
Gemstones	NA	477	NA	836	NA	469
Sand and gravel, construction	16,500	59,300	19,600	74,300	20,800	93,800
Stone, crushed	3,160	15,700	3,420 [r]	18,100 [r]	4,450	23,900
Combined values of cadmium [byproduct of zinc concentrates (2004-05)], cement (portland), copper, feldspar, garnet (industrial), gold (2003, 2005), lead, lime, molybdenum concentrates, perlite (crude), phosphate rock, pumice and pumicite, sand and gravel (industrial), silver, stone (dimension quartzite and sandstone), zeolites (2004-05), zinc	XX	193,000	XX	354,000	XX	788,000
Total	XX	269,000	XX	447,000 [r]	XX	906,000
Illinois:						
Cement, portland	2,930	210,000 [e]	3,010	233,000 [e]	3,240	286,000 [e]
Clays:						
Common	179	1,010	247	1,390	119	667
Fuller's earth	(5)	W	218	W	225	W
Gemstones	NA	28	NA	70	NA	14
Sand and gravel:						
Construction	34,600	161,000	38,700	203,000	37,400	210,000
Industrial	4,440	72,600	4,950	86,200	5,510	104,000
Stone, crushed	76,000 [3]	453,000 [3]	75,300 [r]	462,000 [r]	76,200	545,000
Combined values of lime, peat, stone [crushed sandstone (2003), dimension dolomite (2005)], tripoli, and values indicated by symbol W	XX	74,000	XX	65,000 [r]	XX	64,500
Total	XX	971,000	XX	1,050,000	XX	1,210,000

See footnotes at end of table.

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TABLE 5—Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	2003		2004		2005	
	Quantity	Value	Quantity	Value	Quantity	Value
Indiana:						
Cement, portland	2,930	203,000 e	3,080	218,000 e	3,060	243,000 e
Clays, common	385	767	729	1,890	809	13,500
Gemstones	NA	4	NA	4	NA	4
Sand and gravel, construction	32,900	129,000	28,300	116,000	28,400	135,000
Stone:						
Crushed	50,500	237,000	56,800	265,000 r	57,500	311,000
Dimension	242	42,100	251	45,500	240	46,300
Combined values of cement (masonry), clays (ball), gypsum (crude), lime, peat, sand and gravel (industrial)	XX	104,000	XX	129,000 r	XX	135,000
Total	XX	716,000	XX	776,000 r	XX	,883,000
Iowa:						
Clays, common	256	763	325	1,150	630	4,740
Gemstones	NA	2	NA	2	NA	2
Sand and gravel, construction	13,400	61,000	17,100	74,300	19,900	93,100
Stone, crushed	35,600	207,000	35,800 r	219,000 r	34,500	251,000
Combined values of cement, gypsum (crude), lime, peat, sand and gravel (industrial)	XX	235,000	XX	239,000	XX	292,000
Total	XX	504,000	XX	534,000 r	XX	,641,000
Kansas:						
Cement, portland	2,270	173,000 e	2,690	212,000 e	2,890	244,000 e
Clays, common	632	10,000	621	7,460	654	4,590
Gemstones	NA	1	NA	1	NA	1
Helium, Grade-A million cubic meters	77	179,000	82	189,000	90	226,000
Salt	2,770	123,000	2,890	127,000	2,890	135,000
Sand and gravel, construction	10,700	34,900	9,930	32,800	10,100	36,900
Stone:						
Crushed	20,700	111,000	20,600 r	122,000 r	22,100	159,000
Dimension	15	1,640	14	1,730	13	1,590
Combined values of cement (masonry), clays (fuller's earth), gypsum (crude), helium (crude), pumice and pumicite, sand and gravel (industrial)	XX	65,100	XX	75,300	XX	63,100
Total	XX	696,000	XX	768,000 r	XX	870,000
Kentucky:						
Clays, common	983	3,770	978	4,510	1,060	4,370
Gemstones	NA	22	NA	22	NA	78
Sand and gravel, construction	10,000	46,500	10,300	49,700	10,500	55,000
Stone, crushed	52,400	326,000	62,100 r, 3	384,000 r, 3	58,200 3	421,000 3
Combined values of cement, clays (ball), lime, stone [crushed dolomite (2004-05)]	XX	220,000	XX	253,000 r	XX	285,000
Total	XX	597,000	XX	691,000 r	XX	765,000
Louisiana:						
Clays, common	670	1,690	399	1,030 r	416	13,100
Gemstones	NA	6	NA	6	NA	6
Salt	12,600	152,000	14,300	186,000	13,800	182,000
Sand and gravel:						
Construction	21,200	105,000	19,400	103,000	18,600	113,000
Industrial	499	17,200	476	14,800	509	11,600
Combined values of gypsum (crude), lime, stone [crushed limestone and sandstone (2004-05), limestone, sandstone, miscellaneous (2003)]	XX	91,000	XX	51,300 r	XX	73,800
Total	XX	367 000	XX	356,000	XX	, 393 000
Maine:						
Clays, common	49 e	125 e	49	W	50	W
Gemstones	NA	262	NA	268	NA	272
Sand and gravel, construction	10,400	47,600	10,800	49,100	11,100	57,400
Stone, crushed	3,530	22,500	4,370	29,500	4,490	30,700

See footnotes at end of table.

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TABLE 5—Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	2003		2004		2005	
	Quantity	Value	Quantity	Value	Quantity	Value
Maine—Continued:						
Combined values of cement [masonry (2003-04), portland], peat, stone (dimension granite), and values indicated by symbol W	XX	36,700	XX	39,300	XX	52,400
Total	XX	107,000	XX	118,000	XX	141,000
Maryland:						
Cement, portland	2,200	147,000 e	2,520	175,000 e	3,550	210,000 e
Clays, common	269	550	262	571	317	686
Gemstones	NA	1	NA	1	NA	1
Sand and gravel, construction	11,800	79,900	12,700	75,500	12,300	89,500
Stone:						
Crushed	26,200 3	165,000 3	35,300 r	214,000 r	33,100	274,000
Dimension	24	2,700	27	9,580	26	3,010
Combined values of cement (masonry), sand and gravel (industrial), stone [crushed marble, shell, traprock (2003-04)]	XX	31,700	XX	(7)	XX	(7)
Total	XX	427,000	XX	474,000 r	XX	577,000
Massachusetts:						
Clays, common	36	321	36	(7)	37	(7)
Gemstones	NA	1	NA	1	NA	1
Lime	(5)	(7)	(5)	(7)	(5)	(7)
Sand and gravel, construction	12,900	80,800	14,400	90,000	16,500	117,000
Stone:						
Crushed	13,000	111,000	13,700 r	109,000	13,200	121,000
Dimension	81	11,300	82	11,600	82	11,500
Total	XX	204,000	XX	211,000 r	XX	250,000
Michigan:						
Cement, masonry	237	24,300 e	231	27,100 e	228	27,500 e
Clays, common	588	3,050	605	3,070	334	514
Gemstones	NA	1	NA	1	NA	1
Gypsum, crude	500	6,130	452	5,660	1,050	10,700
Peat	125	3,460	122	3,360	117	3,300
Sand and gravel:						
Construction	71,000	253,000	69,500	254,000	64,800	243,000
Industrial	2,130	31,400	1,690	25,200	1,610	24,500
Stone, crushed	33,600 3	123,000 3	36,700 r, 3	143,000 r, 3	36,100	141,000
Combined values of bromine, cement (portland), iron ore (usable shipped), iron oxide pigments (crude), lime, magnesium compounds, potash, salt, stone [crushed marl and miscellaneous (2003), crushed marl (2004), dimension dolomite and sandstone]	XX	1,140,000	XX	1,210,000	XX	1,300,000
Total	XX	1,580,000	XX	1,680,000 r	XX	1,750,000
Minnesota:						
Clays, common	20	22	20	22	20	22
Gemstones	NA	6	NA	6	NA	6
Iron ore, usable shipped	34,000	1,030,000	41,400	1,560,000	40,600	1,830,000
Lime	(5)	(7)	(5)	(7)	(5)	(7)
Peat	60	5,070	63	5,210	68	5,670
Sand and gravel:						
Construction	48,900	212,000	54,900	235,000	54,100	253,000
Industrial	(5)	(7)	(5)	(7)	(5)	(7)
Stone:						
Crushed	9,880	61,800	10,400 r, 3	64,900 r, 3	10,500	86,900
Dimension	16	11,900	22	12,400	19	13,400
Total	XX	1,320,000	XX	1,880,000 r	XX	2,190,000

See footnotes at end of table.

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TABLE 5—Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		2003 Quantity	2003 Value	2004 Quantity	2004 Value	2005 Quantity	2005 Value
Mississippi:							
Clays:							
Common		524	2,050	610	2,700	642	2,860
Fuller's earth		534	42,700	381	35,200	354	33,000
Gemstones		NA	1	NA	1	NA	1
Sand and gravel, construction		14,600	82,600	14,100	80,700	14,400	85,200
Stone, crushed		2,850	33,900	2,760	34,200	3,500	41,700
Combined values of cement (portland), clays (ball, bentonite), sand and gravel (industrial)		XX	31,400	XX	41,500	XX	52,000
Total		XX	193,000	XX	194,000	XX	215,000
Missouri:							
Cement, portland		5,180	352,000 e	5,260	388,000 e	5,330	464,000 e
Clays:							
Common		970	3,660	911	3,290	822	3,400
Fire		307	7,230	(5)	W	(5)	W
Sand and gravel:							
Construction		10,600	49,400	12,200	60,000	12,200	61,600
Industrial		586	12,800	589	14,200	559	14,500
Stone, crushed		71,500	426,000	92,600 r	564,000 r	99,400	733,000
Combined values of cadmium [byproduct of zinc concentratres (2004-05)], cement (masonry), clays (fuller's earth), copper, gemstones (natural), lead, lime, silver, stone (dimension granite), zinc, and values indicated by symbol W		XX	488,000	XX	593,000	XX	666,000
Total		XX	1,340,000	XX	1,620,000 r	XX	1,940,000
Montana:							
Clays, bentonite		181	14,900	102	8,400	128	5,440
Gemstones		NA	707	NA	653	NA	644
Palladium[4]	kilograms	14,000	91,400	13,700	102,000	13,300	87,100
Platinum[4]	do.	4,170	93,100	4,040	110,000	3,920	113,000
Sand and gravel, construction		15,200	74,200	14,400	80,000	14,000	83,600
Stone:							
Crushed		3,060	12,200	4,090	13,700 r	3,540	16,800
Dimension		14	2,590	14	2,550	12	2,620
Combined values of cadmium [byproduct in zinc concentrates (2004-05)], cement [masonry (2003, 2005), portland], clays (common), copper, garnet [industrial (2005)], gold, lead, lime, molybdenum concentrates, peat, silver, talc (crude), zinc		XX	205,000	XX	303,000	XX	538,000
Total		XX	494,000	XX	621,000 r	XX	847,000
Nebraska:							
Cement:							
Masonry		(5)	(7)	(5)	(7)	(5)	(7)
Portland		(5)	(7)	(5)	(7)	(5)	(7)
Clays, common		133 e	338 e	133 e	338 e	160 e	(7)
Gemstones		NA	4	NA	4	NA	4
Lime		8	692	11	514	12	625
Sand and gravel:							
Construction		13,300	45,000	15,100	53,200	14,300	60,200
Industrial		(5)	(7)	(5)	(7)	--	--
Stone, crushed		6,960	49,200	6,900	51,900	6,950	49,300
Total		XX	95 300	XX	106,000	XX	110,000
Nevada:							
Clays:							
Bentonite		6	817	7	W	7	W
Fuller's earth		28	3,870	(5)	W	(5)	W
Gold[4]	kilograms	227,000	2,660,000	216,000	2,850,000	212,000	3,030,000
Sand and gravel, construction		37,100	174,000	43,100	197,000	52,300	230,000

See footnotes at end of table.

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TABLE 5—Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		2003 Quantity	2003 Value	2004 Quantity	2004 Value	2005 Quantity	2005 Value
Nevada—Continued:							
Silver[4]	kilograms	322,000	50,900	302,000	65,000	276,000	65,200
Stone, crushed		7,830	48,500	9,760	72,800	9,320	66,800
Combined values of barite, brucite (2003-04), cement (portland), clays (kaolin), copper (2004-05), diatomite, gemstones, gypsum (crude), lime, lithium carbonate, magnesite, perlite (crude), salt, sand and gravel (industrial), zeolites (2004-05), and values indicated by symbol W		XX	252,000	XX	286,000	XX	488,000
Total		XX	3,190,000	XX	3,470,000	XX	3,880,000
New Hampshire:							
Gemstones		NA	6	NA	6	NA	6
Sand and gravel, construction		8,470	41,200	8,940	46,600	8,400	47,400
Stone:							
Crushed		4,110	21,400	4,720 r	23,900 r	5,100	40,900
Dimension, granite		(5)	(7)	(5)	(7)	(5)	(7)
Total		XX	62,500	XX	70,500 r	XX	88,200
New Jersey:							
Clays, common		(5)	W	(5)	122	(5)	W
Gemstones		NA	1	NA	1	NA	1
Sand and gravel:							
Construction		18,200	105,000	20,100	120,000	21,200	145,000
Industrial		1,570	32,700	2,020	35,800	1,820	34,100
Stone, crushed		24,800	179,000	25,400 r, 3	185,000 r, 3	22,700	160,000
Combined values of greensand marl, peat, stone [crushed miscellaneous (2004)], and values indicated by symbol W		XX	4,190	XX	4,400 r	XX	4,110
Total		XX	321 000	XX	345 000 r	XX	,344,000
New Mexico:							
Clays, common		36	209	34	177	36	221
Copper[4]		88	165,000	122	362,000	131	502,000
Gemstones		NA	20	NA	20	NA	19
Sand and gravel:							
Construction		13,300	65,300	13,600	89,500	16,000	112,000
Industrial		--	--	--	--	113	W
Silver[4]	kilograms	--	--	3,570	767	6,390	1,510
Stone:							
Crushed		3,730	26,000	2,830 r, 3	16,400 r, 3	3,010	20,100
Dimension		57	2,590	57	2,430	7	279
Combined values of cement, gold (2004-05), gypsum (crude), helium [Grade-A (2003-04)], lime, mica [crude (2003-04)], molybdenum concentrates, perlite (crude), potash, pumice and pumicite, salt, stone [crushed granite (2004)], zeolites (2004-05), and values indicated by symbol W		XX	310,000	XX	397,000 r	XX	513,000
Total		XX	569 000	XX	868 000 r	XX	1 150 000
New York:							
Clays, common		644	8,050	756	10,900	785	11,700
Gemstones		NA	65	NA	74	NA	78
Gypsum, crude		--	--	--	--	2,230	11,400
Salt		5,230	225,000	6,430	301,000	6,840	327,000
Sand and gravel, construction		30,200	172,000	33,100	189,000	31,300	204,000
Stone:							
Crushed		53,700	352,000	49,400 r	327,000 r	52,700	445,000
Dimension		65	6,110	44	4,560	42	7,470
Combined values of cement, garnet (industrial), peat, sand and gravel [industrial (2003-04)], talc (crude), wollastonite		XX	235,000	XX	256,000	XX	286,000
Total		XX	998,000	XX	1,090,000 r	XX	1,290,000

See footnotes at end of table.

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TABLE 5—Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		2003		2004		2005	
		Quantity	Value	Quantity	Value	Quantity	Value
North Carolina:							
Clays:							
Common		2,190	10,900	2,260	12,900	2,180	13,900
Kaolin		(5)	4,500	34	764	27	593
Feldspar		362	18,900	351	20,500	351	19,000
Gemstones		NA	279	NA	280	NA	280
Mica, crude		39	9,580	40	9,600	39	10,200
Sand and gravel:							
Construction		10,500	55,600	11,500	59,700	12,000	63,900
Industrial		1,530	26,700	1,630	29,000	1,150	29,200
Stone:							
Crushed		67,100	505,000	72,300	549,000 r	74,300	638,000
Dimension		47	18,700	43	18,200	39	17,000
Combined values of olivine (2003-04), phosphate rock, pyrophyllite (crude)		XX	84,500	XX	105,000	XX	(7)
Total		XX	734,000	XX	805 000 r	XX	792,000
North Dakota:							
Clays, common		(5)	W	(5)	186	76	W
Gemstones		NA	4	NA	4	NA	4
Sand and gravel, construction		13,500	35,900	11,700	32,800	11,300	34,500
Stone, crushed		(5)	W	(5)	W	89	396
Combined values of lime, sand and gravel (industrial), stone [crushed limestone, volcanic cinder, and miscellaneous (2003), crushed granite, traprock, volcanic cinder, miscellaneous (2004)], and values indicated by symbol W		XX	10,600	XX	11,300 r	XX	10,800
Total		XX	46,500	XX	44 300 r	XX	45 600
Ohio:							
Cement:							
Masonry		(5)	W	1,020	85,700 e	(5)	W
Portland		1,030	82,200 e	98	13,000 e	986	89,200 e
Clays:							
Common		1,440	7,430	1,360	7,480	1,310	6,880
Fire		(5)	W	42	W	55	W
Gemstones		NA	4	NA	4	NA	4
Lime		1,880	114,000	1,880	127,000	1,790	130,000
Sand and gravel:							
Construction		47,300	242,000	50,800	263,000	51,700	288,000
Industrial		1,120	32,100	1,180	34,200	1,230	37,900
Stone:							
Crushed		70,500	339,000	76,500 r	396,000 r	75,200	437,000
Dimension		30	5,090	38	5,100	28	4,880
Combined values of peat, salt, and values indicated by symbol W		XX	188,000	XX	197,000	XX	211,000
Total		XX	1,010,000	XX	1,130,000 r	XX	1,210,000
Oklahoma:							
Clays, common		1,160	2,390	1,150	2,410	903	2,520
Gemstones		NA	197	NA	4	NA	43
Gypsum, crude		2,250	14,100	3,250	20,800	2,620	18,400
Iodine, crude	metric tons	1,090	W	1,130	W	1,570	W
Sand and gravel:							
Construction		11,000	48,500	12,000	53,700	13,300	65,000
Industrial		1,360	29,700	1,390	31,600	1,480	33,500
Stone:							
Crushed		40,100	193,000	39,800 r	206,000 r	45,400	257,000
Dimension		17	2,100	17	2,100	3	501
Tripoli	metric tons	10,600	1,960	32,100	2,120	30,600	1,950

See footnotes at end of table.

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TABLE 5—Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		2003 Quantity	2003 Value	2004 Quantity	2004 Value	2005 Quantity	2005 Value
Oklahoma—Continued:							
Combined values of cement, feldspar, helium (Grade-A), lime, salt, and values indicated by symbol W		XX	179,000	XX	199,000	XX	227,000
Total		XX	470,000	XX	519,000 r	XX	606,000
Oregon:							
Clays, bentonite		(5)	W	10	W	9	W
Gemstones		NA	1,200	NA	1,210	NA	1,180
Sand and gravel, construction		18,500	110,000	21,000	125,000	22,000	146,000
Stone, crushed		21,800	117,000	22,700 r	126,000	26,000	157,000
Zeolites	metric tons	(5)	NA	--	--	--	--
Combine values of cement (portland), clays (common), diatomite, lime, perlite (crude), pumice and pumicite, talc (crude), and values indicated by symbol W		XX	92,700	XX	114,000	XX	128,000
Total		XX	,320 000	XX	367,000	XX	,432,000
Pennsylvania:							
Cement:							
Masonry		342	35,900 e	(5)	W	399	49,700 e
Portland		5,720	421,000 e	6,230	473,000 e	6,290	554,000 e
Clays, common		750	2,240	822	3,270	705	3,460
Gemstones		NA	1	NA	1	NA	1
Lime		1,190	90,100	1,220	100,000	1,100	104,000
Peat		8	219	11	307	7	210
Sand and gravel:							
Construction		18,400	115,000	20,000	127,000	17,000	111,000
Industrial		(5)	W	(5)	W	711	15,400
Stone:							
Crushed		104,000	597,000	113,000 r	639,000 r	106,000	704,000
Dimension		32	10,400	33	10,100	35	11,800
Combined values of tripoli and values indicated by symbol W		XX	(7)	XX	55,800	XX	(7)
Total		XX	1,270,000	XX	1,410,000 r	XX	1,550,000
Rhode Island:							
Gemstones		NA	1	NA	1	NA	1
Sand and gravel:							
Construction		2,450	21,000	2,490	22,000	2,510	23,000
Industrial		(5)	(7)	(5)	(7)	(5)	(7)
Stone, crushed		1,340	10,700	1,600 3	12,400 3	1,610 4	12,400 4
Total		XX	31,700	XX	34,400	XX	35,400
South Carolina:							
Cement:							
Masonry		425	43,700 e	453	49,900 e	498	54,300 e
Portland		3,150	194,000 e	3,110	196,000 e	3,270	247,000 e
Clays:							
Common		1,060	2,660	1,050	3,350	1,020	3,610
Fire		(5)	W	1	64	54	892
Kaolin		355	21,700	296	19,600	287	17,700
Gemstones		NA	1	NA	1	NA	1
Sand and gravel:							
Construction		10,100	34,700	9,960	35,100	11,100	45,200
Industrial		655	16,700	719	17,600	794	19,400
Stone:							
Crushed		27,300	184,000	31,300	210,000	33,800 3	258,000 3
Dimension		9	850	9	850	9	850
Combined values of mica (crude), stone [crushed marble (2005)], vermiculite (crude), and value indicated by symbol W		XX	10,100	XX	(7)	XX	12,600
Total		XX	508,000	XX	532,000	XX	659,000

See footnotes at end of table.

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TABLE 5—Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral		2003 Quantity	2003 Value	2004 Quantity	2004 Value	2005 Quantity	2005 Value
South Dakota:							
Clays, common		213	W	188	W	183	W
Sand and gravel, construction		11,800	44,800	14,000	51,700	12,800	45,500
Stone, crushed		6,880	24,700	6,410 r	27,600 r	6,650	30,600
Combined values of cement (portland), feldspar, gemstones, gold, gypsum (crude), lime, mica crude), stone (dimension granite), and values indicated by symbol W		XX	130,000	XX	131,000	XX	139,000
Total		XX	199,000	XX	210,000 r	XX	215,000
Tennessee:							
Clays:							
Ball		766	33,400	762	34,300	740	32,500
Common		304	585	365	3,140	372	3,210
Fuller's earth		92 e	5,000 e	(5)	W	(5)	W
Sand and gravel:							
Construction		7,550	44,100	7,830	47,500	7,570	51,500
Industrial		961	21,800	975	26,100	985	26,500
Stone, crushed		55,100	354,000	57,900	381,000 r	63,900	482,000
Combined values of cadmium [byproduct in zinc concentrates (2004)], cement, clays (kaolin), gemstones, lime, salt, stone (dimension marble), zinc (2003-04), and values indicated by symbol W		XX	164,000	XX	160,000 r	XX	174,000
Total		XX	623 000	XX	652,000 r	XX	,770,000
Texas:							
Cement:							
Masonry		307	36,100 e	319	38,000 e	395	48,500 e
Portland		11,100	747,000 e	11,200	800,000 e	11,600	951,000 e
Clays:							
Common		2,110	8,890	2,160	8,890	2,340	8,680
Fuller's earth		27	2,400	(5)	W	(5)	W
Kaolin		33	7,150	(5)	W	(5)	W
Gemstones		NA	201	NA	201	NA	201
Gypsum, crude		1,810	12,300	2,450	18,800	1,540	11,800
Lime		1,630	110,000	1,630	115,000	1,610	112,000
Salt		9,640	116,000	9,870	118,000	9,600	118,000
Sand and gravel:							
Construction		86,200	425,000	81,700	436,000	80,700	472,000
Industrial		1,930	81,700	2,790	109,000	2,840	114,000
Stone:							
Crushed		126,000	595,000	122,000	621,000 r	134,000	823,000
Dimension		87	16,400	64	15,200	44	12,200
Talc, crude		246	W	258	W	(5)	W
Combined values of brucite, clays (ball, bentonite), helium, zeolites (2004-05), and values indicated by symbol W		XX	33,300	XX	46,300	XX	49,300
Total		XX	2,190,000	XX	2 330,000 r	XX	2,720,000
Utah:							
Beryllium concentrates	metric tons	2,100	NA	2,210	NA	2,780	NA
Clays:							
Bentonite		(5)	W	73	W	64	W
Common		300	3,270	443	5,600	478	6,710
Gemstones		NA	233	NA	235	NA	235
Salt		2,200	119,000	2,250	107,000	2,250	132,000
Sand and gravel, construction		27,400	113,000	29,800	125,000	33,900	149,000
Stone, crushed		7,820	40,100	8,030 r	45,100 r	8,350	46,600

See footnotes at end of table.

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TABLE 5—Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	2003 Quantity	2003 Value	2004 Quantity	2004 Value	2005 Quantity	2005 Value
Utah—Continued:						
Combined values of cement (portland), copper, gold, gypsum (crude), helium (Grade-A), lime, magnesium compounds, magnesium metal, molybdenum concentrates, perlite (crude), phosphate rock, potash, silver, stone (dimension sandstone), and values indicated by symbol W	XX	1,080,000	XX	1,660,000	XX	2,460,000
Total	XX	1,360,000	XX	1,950,000 r	XX	2,790,000
Vermont:						
Gemstones	NA	1	NA	1	NA	1
Sand and gravel, construction	4,520	21,100	4,970	24,000	5,240	32,000
Stone:						
Crushed	4,290	23,900	5,110	30,800	5,480 3	37,000 3
Dimension	102	26,700	100	30,600	98	27,800
Talc, crude metric tons	(5)	(7)	(5)	(7)	(5)	(7)
Total	XX	71,800	XX	85,400	XX	96,800
Virginia:						
Clays:						
Bentonite	--	--	5	W	--	--
Common	958	2,530	994	4,640	983	4,690
Kyanite e	90	13,400	90	13,400	90	13,400
Sand and gravel, construction	11,300	65,500	12,800	75,800	12,000	85,800
Stone:						
Crushed	66,500	481,000	73,700 r, 3	540,000 r, 3	86,200	778,000
Dimension	6	651	5	594	6	631
Talc, crude	--	--	--	--	1	15
Combined values of cement, clays (fuller's earth), feldspar, gemstones, iron oxide pigments (crude), lime, sand and gravel (industrial), stone [crushed marble (2004)], titanium concentrates (ilmenite), vermiculite (crude), zirconium concentrates, and value indicated by symbol W	XX	223,000	XX	256,000 r	XX	272,000
Total	XX	786,000	XX	891,000 r	XX	1,160,000
Washington:						
Clays, common	83	204	(5)	W	(5)	W
Gemstones	NA	44	NA	44	NA	44
Sand and gravel, construction	40,700	216,000	41,500	227,000	47,200	282,000
Stone, crushed	12,000	73,700	12,100 r	75,500 r	13,900	96,300
Combined values of cadmium byproduct in zinc concentrates (2004-05), cement (portland), diatomite, gold (2004-05), lead (2004-05), lime, olivine, peat, sand and gravel (industrial), silver (2004-05), stone [dimension miscellaneous (2004-05)], zinc (2004-05), and values indicated by symbol W	XX	107,000	XX	205,000	XX	255,000
Total	XX	,396 000	XX	507,000	XX	,633,000
West Virginia:						
Clays, common	142	376	161	441	186	524
Gemstones	NA	1	NA	1	NA	1
Sand and gravel:						
Construction	971	4,750	524	2,500	318	1,630
Industrial	(5)	W	343	17,300	369	17,800
Stone, crushed	14,100	69,100	14,700	72,600 r	14,500	99,400
Combined values of cement, lime, peat, salt, stone (dimension sandstone), and value indicated by symbol W	XX	90,100	XX	73,500	XX	81,100
Total	XX	164,000	XX	166,000 r	XX	200,000

See footnotes at end of table.

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TABLE 5—Continued
NONFUEL MINERAL PRODUCTION IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral	2003		2004		2005	
	Quantity	Value	Quantity	Value	Quantity	Value
Wisconsin:						
Cement, portland	(5)	(7)	(5)	(7)	(5)	(7)
Gemstones	NA	6	NA	6	NA	6
Lime	757	46,000	850	53,900	888	61,300
Peat	(5)	(7)	(5)	(7)	(5)	(7)
Sand and gravel:						
Construction	38,500	150,000	43,400	178,000	43,200	191,000
Industrial	1,930	40,200	2,140	47,000	2,250	55,700
Stone:						
Crushed	35,900	160,000	39,300 r	172,000 r	38,900	227,000
Dimension	101	19,700	232	23,800	278	27,600
Total	XX	417,000	XX	475,000 r	XX	562,000
Wyoming:						
Clays:						
Bentonite	3,420	148,000	3,510	151,000	4,160	190,000
Common	25	55	49	107	53	128
Gemstones	NA	13	NA	13	NA	14
Sand and gravel, construction	8,290	36,400	10,200	40,100	11,700	52,400
Stone, crushed	5,020	22,600	6,300 r	35,300 r	7,370	41,800
Combined values of cement (portland), gypsum (crude), helium (Grade-A), lime, soda ash, zeolites (2004-05)	XX	792,000	XX	819,000	XX	1,010,000
Total	XX	999,000	XX	1,050,000 r	XX	1,300,000
Undistributed:						
Connecticut, Delaware, Hawaii (2003), Maryland (2005), Massachusetts, Minnesota, Nebraska, New Hampshire, North Carolina (2005), Pennsylvania (2003, 2005), Rhode Island, South Carolina (2004), Vermont, Wisconsin, undistributed	XX	220,000	XX	193,000 r	XX	431,000

eEstimated. rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data; included in "Combined values" data for each State. XX Not applicable. -- Zero.

[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producers)

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Excludes certain stones; kind and value included in "Combined value."

[4]Recoverable content of ores, etc.

[5]Withheld to avoid disclosing company proprietary data.

[6]Grindstones, pulpstones, and sharpening stones; excludes mill liners and grinding pebbles.

[7]Withheld to avoid disclosing company proprietary data; values included in "Undistributed."

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TABLE 6
NONFUEL RAW MINERAL PRODUCTION IN THE COMMONWEALTH OF PUERTO RICO AND ISLANDS ADMINISTERED BY THE UNITED STATES[1, 2]

(Thousand metric tons and thousand dollars)

Mineral	2003		2004		2005	
	Quantity	Value	Quantity	Value	Quantity	Value
Puerto Rico:						
Cement, portland	1,490	W	1,580	W	1,580	W
Clays, common	114	585	114	585	116	596
Lime	(3)	W	11	2,250	11	2,250
Salt	45	1,500	45	1,500	45	1,500
Stone, crushed	9,130	60,000	8,660	57,600	7,830	51,900
Combined values of sand and gravel (industrial), stone (dimension marble), and values indicated by symbol W	XX	119,000	XX	125,000	XX	153,000
Total	XX	181,000	XX	187,000	XX	209,000
Administered Islands:						
American Samoa, stone, crushed, traprock	(3)	(3)	(3)	(3)	(3)	(3)
Guam, stone, crushed	728	7,670	1,410	13,000	1,410	13,000
Virgin Islands, stone, crushed, limestone and traprock	(3)	(3)	(3)	(3)	257	2,730
Total	XX	7,670	XX	13,000	XX	15,800

W Withheld to avoid disclosing company proprietary data; withheld values included in "Combined values" data. XX Not applicable.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Production as measured by mine shipments, sales, or marketable production (including consumption by producers)

[3]Withheld to avoid disclosing company proprietary data.

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TABLE 7

U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		2004		2005	
		Quantity	Value	Quantity	Value
Metals:					
Aluminum:					
Crude and semicrude	metric tons	1,820,000	4,130,000	2,370,000	5,410,000
Manufactures	do.	129,000	437,000	135,000	482,000
Antimony:					
Metal, alloys, waste and scrap	do.	566	2,280	740	3,250
Oxide, antimony content	do.	3,240	13,200	1,400	5,860
Arsenic metal, arsenic content	do.	220	20,700	327	30,700
Bauxite and alumina:					
Alumina, calcined equivalent		1,230	439,000	1,210	631,000
Bauxite:					
Calcined, refractory and other grade		21	2,950	18	2,330
Crude and dried		42	7,910	34	7,020
Speciality aluminum compounds, sulfate, chloride, fluoride-based	metric tons	26,500 r	20,600 r	26,900	21,600
Beryllium, unwrought, and waste and scrap, other including articles not elsewhere specified	kilograms	217,000	19,600	201,000	16,300
Bismuth, metal, alloys, waste and scrap, bismuth content	do.	109,000	2,500	142,000	4,760
Cadmium:					
Metal, includes cadmium in alloys and scrap	do.	132,000	861	668,000	1,330
Sulfide, gross weight	do.	160,000	76	120,000	55
Chromium:					
Ores and concentrate	metric tons	43,100	10,400	42,600	9,940
Metals and alloys:					
Metal, unwrought powders, waste and scrap, other	do.	931	17,600	1,020	16,900
Ferroalloys, high-carbon, low-carbon, ferrochromium-silicon	do.	9,140	12,000	36,300	38,900
Chemicals:					
Oxides, trioxides and other	do.	12,900	22,200	10,700	18,300
Sulfates	do.	39	417	79	376
Salts of oxometallic or peroxometallic acids, zinc and lead chromate, sodium dichromate, potassium dichromate, other	do.	21,800	14,400	37,900	27,200
Pigments and preparations	do.	671	3,780	767	4,090
Cobalt:					
Acetates and chlorides	do.	666	5,490	703	3,820
Oxides and hydroxides	do.	324	13,800	829	17,100
Metal:					
Unwrought, powders, waste and scrap, mattes, other intermediate products of metallurgy	do.	2,110	79,400	1,670	60,600
Wrought and cobalt articles	do.	1,150	48,400	2,340	91,800
Columbium (niobium) and tantalum:					
Columbium:					
Ores and concentrates	do.	16	108	43	398
Ferrocolumbium	do.	294	2,920	410	4,210
Tantalum:					
Ores and concentrates, includes synthetic	do.	723	19,300	545	9,300
Unwrought, waste and scrap, powders, alloys, metal	do.	598	173,000	699	136,000
Wrought	do.	162	83,400	110	49,000
Copper:					
Unmanufactured, does not include unalloyed scrap, copper content	do.	211,000	429,000	260,000	467,000
Semimanufactures	do.	236,000	863,000	254,000	1,100,000
Scrap, alloyed and unalloyed	do.	714,000	882,000	658,000	1,060,000
Ferroalloys not listed elsewhere:					
Ferrophosphorous	do.	388	335	NA	NA
Other	do.	1,620	2,670	NA	NA
Gold:					
Ores and concentrates	kilograms	1,150	10,200	1,380	13,400
Dore and precipitates	do.	142,000	1,860,000	141,000	2,020,000
Bullion, refined	do.	114,000	1,500,000	182,000	2,550,000
Waste and scrap	do.	725,000 r	815,000	563,000	670,000

See footnotes at end of table.

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TABLE 7—Continued

U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		2004		2005	
		Quantity	Value	Quantity	Value
Metals—Continued:					
Gold—Continued:					
Metal powder	kilograms	647	8,670	687	9,280
Compounds	do.	1,170,000	29,000	1,310,000	30,900
Indium[e]	metric tons	NA	NA	NA	NA
Iron and steel:					
Steel mill products		7,200	9,280,000	8,460	NA
Fabricated steel products		1,470 r	4,340,000	1,710	NA
Cast iron and steel products		234	661,000	193	NA
Iron and steel scrap:					
Ferrous, includes tinplate and ternplate, excludes used rails for rerolling and other uses and ships, boats, and other vessels for scrapping		11,800	2,910,000	13,000	3,430,000
Pig iron, all grades		48	6,690	51	8,110
Direct-reduced iron, steelmaking grade		13	1,360	(2)	16
Ships, boats, and other vessels for scrapping		16	2,680	3	476
Used rails for rerolling and other uses, includes mixed (used plus new) rails		42	18,100	55	25,600
Iron ore		8,400	334,000	11,800	584,000
Lead:					
Base bullion, Pb content	metric tons	129	841	198	1,290
Ore and concentrates, Pb content	do.	292,000	157,000	390,000	190,000
Unwrought and alloys, Pb content	do.	58,600	50,100	45,500	46,100
Wrought and alloys, Pb content	do.	23,800	42,300	19,000	40,800
Scrap, gross weight	do.	56,300	14,800	67,300	21,600
Magnesium:					
Waste and scrap, Mg content	do.	4,790	11,300	5,630	13,100
Metal, Mg content	do.	1,760	3,830	732	2,470
Alloys, gross weight	do.	1,750	7,780	1,200	5,870
Powder, sheets, tubing, ribbons, wire, other forms, gross weight	do.	3,530	25,800	2,080	22,400
Manganese, gross weight:					
Ores and concentrates with 20% or more manganese	do.	123,000	12,400	13,500	3,940
Ferromanganese, all grades	do.	9,120	10,600	14,400	14,900
Silicomanganese	do.	502	632	899	1,220
Metal, including alloys and waste and scrap	do.	2,790	6,090	2,670	5,960
Dioxide	do.	4,000	3,680	5,900	5,040
Mercury:					
Metal	do.	278	2,310	319	5,810
Amalgams of precious metals whether or not chemically defined	do.	603	155,000	1,160	231,000
Molybdenum:					
Ore and concentrates, including roasted and other, Mo content	do.	46,200	358,000	46,400	1,450,000
Chemicals:					
Oxides and hydroxides, gross weight	do.	5,280	80,300	14,600	375,000
Molybdates, all, gross weight	do.	2,680	28,500	2,150	54,500
Ferromolybdenum, Mo content	do.	925	21,200	2,090	43,400
Other, includes powders, unwrought, bars and rods, waste and scrap, wire, other, gross weight	do.	1,520	66,000	2,030	139,000
Nickel, Ni content:					
Primary, unwrought and chemicals	do.	8,000	186,000	7,630	219,000
Secondary, stainless steel scrap and waste and scrap	do.	48,300	609,000	55,600	731,000
Wrought, not alloyed, bars, rods, profiles, wire, sheets, strip, foil, tubes, pipes	do.	1,120	16,400	1,340	26,700
Alloyed, unwrought ingot, bars, rods, profiles, wire, sheets, strip, foil, tubes, pipes, other alloyed articles, gross weight	do.	29,700	566,000	37,700	819,000
Platinum-group metals:					
Palladium, Pd content	kilograms	31,500 r	143,000 r	27,000	122,000
Platinum, includes waste and scrap, Pt content	do.	28,400 r	520,000 r	24,900	482,000
Iridium, osmium, ruthenium, gross weight	do.	1,090 r	8,800 r	1,070	7,190
Rhodium, Rh content	do.	314 r	7,900 r	615	28,900

See footnotes at end of table.

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TABLE 7—Continued
U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		2004		2005	
		Quantity	Value	Quantity	Value
Metals—Continued:					
Rare earths, estimated rare-earth oxide content:					
Cerium compounds	kilograms	2,280,000	12,600	2,220,000	13,600
Compounds, inorganic and organic	do.	4,800,000	18,900	2,070,000	14,100
Metals, including scandium and yttrium	do.	1,010,000	6,050	636,000	5,180
Ferrocerium and other pyrophoric alloys	do.	3,720,000	16,800	4,320,000	18,000
Selenium, Se content	do.	160,000	2,820 r	254,000	3,040
Silicon, gross weight:					
Ferrosilicon	metric tons	11,500	11,700	13,400	13,400
Metal	do.	18,600	489,000	23,400	847,000
Silver:					
Bullion, Ag content	kilograms	302,000	64,500	166,000	45,900
Dore, Ag content	do.	79,800	18,800	132,000	35,000
Metal powder, gross weight	do.	708,000	122,000	809,000	139,000
Nitrate, gross weight	do.	61,500	5,720	56,600	4,180
Ores and concentrates, Ag content	do.	1,560	306	3,680	834
Semimanufactured forms containing 99.5% or more by weight of silver, gross weight	do.	269,000	48,300	308,000	54,500
Waste and scrap, gross weight	do.	2,240,000	424,000	2,880,000	576,000
Unwrought, other, gross weight	do.	39,600	8,690	20,500	5,280
Thallium, unwrought powders, waste and scrap, others	do.	1,190	276	252	102
Thorium and thorium-bearing materials, thorium ore, monazite concentrate, compounds	do.	731	298	737	281
Tin:					
Ingots and pigs	metric tons	3,650	25,700	4,330	30,500
Tin scrap and other tin bearing material, except tinplate scrap, includes rods, profiles, wire, powders, flakes, tubes, pipes	do.	16,800	42,900	32,800	51,200
Tinplate and terneplate	do.	262,000	169,000	252,000	188,000
Titanium:					
Metal, waste and scrap, unwrought, wrought products and castings, ferrotitanium and ferrosilicon titanium	do.	25,200	417,000 r	39,500	677,000
Ores and concentrates	do.	8,690	3,370	20,900	8,930
Pigment, dioxide and oxide	do.	635,000	1,090,000	524,000	1,060,000
Tungsten, W content:					
Ammonium paratungstate	do.	125	722	774	8,810
Carbide powder	do.	1,440 e	24,200	1,560 e	37,800
Metal powders	do.	433 e	18,700	750 e	28,500
Miscellaneous tungsten-bearing materials, ferrotungsten, ferrosilicon tungsten, unwrought, waste and scrap, wrought, compounds	do.	1,730	43,700	2,810	63,400
Ores and concentrates	do.	43 e	959	52 e	1,600
Vanadium:					
Aluminum-vanadium master alloy, gross weight	kilograms	14,600,000	32,200 r	15,100,000	45,600
Ferrovanadium, V content	do.	285,000	9,210	504,000	19,300
Metal, including waste and scrap, gross weight	do.	522,000	7,770 r	293,000	16,400
Pentoxide, anhydride, V content	do.	240,000 r	4,350 r	254,000	5,470
Other oxides and hydroxides, V content	do.	584,000 r	6,230	899,000	15,400
Zinc:					
Compounds, chloride, compounds, n.s.p.f., oxide, sulfate	do.	27,200	38,100	29,700	47,200
Ores and concentrates, Zn content	do.	745,000 r	413,000	786,000	477,000
Rolled	do.	9,770	12,700	8,760	10,400
Slab	do.	3,300	5,330	784	1,500
Zirconium:					
Ferrozirconium	do.	913	1,310	65	100
Ores and concentrates	do.	68,800	45,500	101,000	74,000
Oxide, includes germanium oxides and zirconium dioxides	do.	1,600	18,100	2,260	21,000
Unwrought powders	do.	138	2,600	175	3,620
Waste and scrap	do.	1,560	92,400	1,800	90,300
Total		XX	36,400,000 r	XX	28,900,000

See footnotes at end of table.

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TABLE 7—Continued
U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		2004		2005	
		Quantity	Value	Quantity	Value
Industrial minerals:					
Abrasives, manufactured:					
Aluminum oxide, crude	kilograms	13,900	41,200	13,900	45,100
Metallic abrasives	do.	26,500	20,600	26,900	21,600
Silicon carbide, crude, ground and refined	do.	13,900	14,600	15,600	17,400
Asbestos, includes reexports:					
Manufactured	metric tons	NA	341,000	NA	374,000
Unmanufactured	do.	1,580	333,000	1,510	398,000
Barite, natural barium sulfate	do.	69,900	6,400	92,700	9,930
Boron minerals and compounds:					
Boric acid, includes orthoboric and anhydrous		61	35,000	183	96,800
Sodium borates		135	60,200	308	110,000
Bromine:					
Compounds, includes methyl bromine and ethylene dibromide, Br content	metric tons	6,600	13,800	6,830	16,800
Elemental, gross weight	do.	2,840	2,070	2,710	3,990
Cement, hydraulic and clinker		818	63,000	803	68,300
Clays:					
Ball		107	8,200	141	8,840
Bentonite		915	105,000	847	98,500
Fire		332	32,300	368	34,400
Fuller's earth		49	10,300	55	13,500
Kaolin		3,640	600,000	3,580	601,000
Other, n.e.c., includes chamotte or dinas earth, activated clays and earths, artifically activated clays		586	181,000	634	173,000
Diamond:					
Gemstones, natural, including reexports	thousand carats	22,600 r	6,870,000 r	25,700	8,470,000
Industrial including exports and reexports:					
Unworked	do.	2,340	21,700	1,430	26,100
Powder, dust and grit, natural and synthetic	do.	97,900	51,600	104,000	59,300
Diatomite		143	53,700	142	60,400
Feldspar	metric tons	9,630	1,420	15,200	2,070
Fluorspar	do.	20,600	3,200	36,100	7,840
Garnet, industrial[e]		11	8,990	13	9,700
Graphite, natural and artificial	metric tons	94,900	118,000 r	56,200	109,000
Gypsum and gypsum products:					
Crude		149	15,000	148	16,400
Plasters		332	31,800	174	33,700
Boards		83	51,100	86	58,900
Other		XX	29,300	XX	33,000
Helium, Grade-A	million cubic meters	45	87,400	51	99,100
Iodine:					
Crude/resublimed	metric tons	1,270	11,800	2,660	27,900
Potassium iodide	do.	102 r	1,980 r	68	1,550
Iron oxide pigments and hydroxides:					
Pigment grade	do.	3,120	7,380	2,220	6,170
Other grade	do.	72,700	41,800	73,100	47,100
Kyanite, andalusite, sillimanite		35 r	6,200 r	35	7,200
Lime		100	14,300 r	133	17,500
Lithium chemicals:					
Carbonate	metric tons	3,910	12,200	4,190	13,700
Hydroxide	do.	5,780	20,000	5,620	20,100
Magnesium compounds:					
Compounds, chlorides, hydroxide and peroxide, sulfates	do.	41,100	18,100	32,700	19,500
Magnesite, crude and processed:					
Caustic-calcined magnesia	do.	3,720	2,200	4,920	2,500
Dead-burned and fused magnesia	do.	29,900	17,300	24,900	11,400
Other magnesia	do.	23,400 r	17,700 r	21,700	18,300
Crude	do.	19,500	2,250	21,800	2,490

See footnotes at end of table.

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TABLE 7—Continued

U.S. EXPORTS OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		2004		2005	
		Quantity	Value	Quantity	Value
Industrial minerals—Continued:					
Mica:					
Scrap and flake:					
Powder	metric tons	7,200	4,780	7,140	4,860
Waste	do.	2,730	731	1,480	343
Sheet:					
Unworked	do.	29	58	74	269
Worked	do.	1,060 r	15,000 r	1,350	13,900
Peat		29	3,390	36	4,020
Perlite, crude e	metric tons	37,000	1,500	32,000	1,300
Pumice and pumicite		27	7,000	20	7,520
Salt		1,110	47,600	879	51,800
Sand and gravel:					
Construction:					
Sand		124	27,500	137	23,400
Gravel		553	4,610	382	4,800
Industrial		1,790	174,000	2,910	154,000
Silica, special stone products		NA	8,900	NA	10,000
Soda ash		4,670	514,000	4,680	640,000
Stone:					
Crushed		1,290 r	54,500	1,270	50,500
Dimension		XX	63,700	XX	66,100
Strontium compounds:					
Carbonate, precipitated	metric tons	360	266	66	196
Oxide, hydroxide, peroxide	do.	469	477	301	176
Sulfur:					
Elemental		949	63,300	684	55,200
Sulfuric acid, 100% H_2SO_4	metric tons	204,000	21,300	338,000	29,500
Talc, excludes powders, talcum (in package), face, compact		202	39,600	198	41,800
Vermiculite e		10	1,600	5	970
Wollastonite e	metric tons	12,500	3,750	7,000	2,100
Zeolites e	do.	1,000	200	5,000	1,000
Total		XX	10,400,000	XX	12,400,000
Grand total		XX	46,900,000 r	XX	41,400,000

eEstimated. rRevised. NA Not available. XX Not applicable.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

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TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		2004		2005	
		Quantity	Value	Quantity	Value
Metals:					
Aluminum:					
Crude and semicrude	metric tons	4,720,000	9,240,000	5,330,000	11,500,000
Manufactures	do.	288,000	756,000	337,000	964,000
Antimony:					
Metal	do.	8,270	19,100	6,370	20,400
Ore and concentrate, antimony content	do.	1,750	4,900	204	622
Oxide, antimony content	do.	23,500	67,200	22,700	81,600
Arsenic:					
Acid	do.	22	32	9	50
Metal	do.	872	3,030	812	3,410
Sulfide	do.	(2)	2	--	--
Trioxide	do.	8,090	4,080	11,000	5,280
Bauxite and alumina:					
Alumina, calcined equivalent		1,650	533,000	1,860	639,000
Bauxite:					
Calcined, refractory and other grade		341	36,900	337	37,300
Crude and dried		10,000	186,000	9,850	246,000
Speciality aluminum compounds, sulfate, chloride, fluoride-based	metric tons	11,900	6,360	14,800	7,620
Beryllium, ore, concentrates, oxide, hydroxide, unwrought including powders, waste and scrap, other, beryllium-copper master alloys, beryllium-copper plates, sheets, strip[3]	kilograms	1,280,000	14,200	1,040,000	16,300
Bismuth, metallic	do.	1,980,000	14,500	2,530,000	20,500
Cadmium:					
Metal	do.	38,000	127	81,300	1,040
Sulfide, gross weight	do.	1,810	23	8,760	75
Chromium:					
Chromite ore	metric tons	153,000	17,500	165,000	23,100
Metals and alloys:					
Ferrochromium-silicon	do.	30,600	31,500	33,700	31,600
Metal, unwrought powders, waste and scrap, other	do.	9,630	56,000	11,000	87,700
Chemicals:					
Oxides, hydroxides, trioxides and other	do.	9,960	18,900	14,600	32,600
Sulfates	do.	111	161	288	438
Salts of oxometallic or peroxometallic acids, zinc and lead chromate, sodium dichromate, potassium dichromate, other	do.	1,880	3,430	9,890	7,460
Carbide	do.	138	1,630	131	2,150
Pigments and preparations based on chromium	do.	7,540	20,200	7,510	22,100
Cobalt:					
Metal:					
Alloys, unwrought, waste and scrap, wrought, cobalt articles	do.	1,330	29,500	1,170	28,300
Unwrought, excluding alloys and waste and scrap, includes cathode and metal powder, may include intermediate products of cobalt metallurgy	do.	7,250	311,000	9,350	312,000
Oxide and hydroxides	do.	1,300	45,100	1,310	35,100
Other forms, includes acetates, carbonates, chlorides, sulfates	do.	1,720	22,100	2,200	24,800
Columbium (niobium) and tantalum:					
Columbium:					
Ores and concentrates	do.	5	41	10	119
Oxide	do.	906	13,900	946	13,400
Ferrocolumbium	do.	7,950	69,000	8,360	71,700
Unwrought, alloys, metal, powder	do.	940	18,500	1,380	26,700
Tantalum:					
Ores and concentrates, includes synthetic concentrates	do.	1,480 r	57,900 r	1,250	43,700
Unwrought, waste and scrap, powders, alloys, metal	do.	1,060	138,000	1,160	105,000
Wrought	do.	38	10,000	78	17,100

See footnotes at end of table.

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TABLE 8—Continued

U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		2004		2005	
		Quantity	Value	Quantity	Value
Metals—Continued:					
Copper:					
Unmanufactured, does not include unalloyed scrap, copper content	metric tons	983,000	2,650,000	1,140,000	3,970,000
Semimanufactures	do.	390,000	1,270,000	524,000	1,940,000
Scrap, alloyed and unalloyed	do.	102,000	187,000	114,000	276,000
Ferroalloys not listed elsewhere:					
Ferrophosphorus	do.	7,280	1,840	NA	NA
Other	do.	8,520	12,700	NA	NA
Gallium:					
Unwrought and waste and scrap	kilograms	19,400	4,130	15,800	4,900
Gallium arsenide wafers, doped and undoped	do.	230,000	154,000	204,000	163,000
Germanium, wrought, unwrought, waste and scrap, gross weight	do.	9,130	7,260	16,700	11,200
Gold:					
Ores and concentrates	do.	1,860	19,200	1,630	18,900
Dore and precipitates	do.	142,000	1,590,000	234,000	2,060,000
Bullion, refined	do.	139,000	1,830,000	105,000	1,520,000
Waste and scrap	do.	20,500	161,000	27,300	209,000
Metal powder	do.	10,900	59,400	1,990	6,730
Compounds	do.	60,000	1,530	29,500	935
Indium, unwrought and waste and scrap	do.	143,000	58,800	142,000	94,300
Iron and steel:					
Steel mill products		32,500	21,400,000	29,200	NA
Fabricated steel products		4,740	8,260,000	5,120	NA
Cast iron and steel products		611	638,000	744	NA
Stainless steel	metric tons	560,000	2,490,000	585,000	NA
Iron and steel scrap:					
Ferrous, includes tinplate and ternplate, excludes used rails for rerolling and other uses and ships, boats, and other vessels for scrapping		4,660	1,230,000	3,840	909,000
Pig iron, all grades		6,400	1,360,000	6,030	1,580,000
Direct-reduced iron, steelmaking grade		2,450	463,000	2,170	361,000
Ships, boats, and other vessels for scrapping		(2)	128	(2)	208
Used rails for rerolling and other uses, includes mixed (used plus new) rails		131 r	44,100	164	62,800
Iron ore		11,800	371,000	13,000	532,000
Lead:					
Pigs and bars, Pb content	metric tons	197,000	175,000	298,000	303,000
Pigments and compounds, Pb content	do.	33,200	48,000	32,500	55,500
Scrap, reclaimed, includes ash and residues, Pb content	do.	4,780	3,510	3,340	2,880
Wrought, all forms, including wire and powders, gross weight	do.	11,000	25,200	11,900	28,900
Magnesium:					
Waste and scrap, gross weight	do.	11,700	17,600	14,700	22,700
Metal, gross weight	do.	34,300	78,200	28,700	80,700
Alloys, Mg content	do.	51,500	152,000	40,300	139,000
Powder, sheets, tubing, ribbons, wire, other forms, Mg content	do.	1,180 r	10,200	1,040	10,100
Manganese:					
Ores and concentrates with 20% or manganese, all grades, Mn content	do.	234,000	37,700	334,000	58,200
Ferromanganese, all grades, Mn content	do.	335,000 r	414,000 r	202,000	200,000
Silicomanganese, Mn content	do.	269,000	386,000	218,000	231,000
Metal, unwrought, other wrought, waste and scrap, gross weight	do.	34,700	49,900	33,400	57,500
Chemicals, manganese dioxide and potassium permanganate, gross weight	do.	27,600	33,000	32,600	41,600
Mercury:					
Metal	do.	92	1,350	212	2,530
Amalgams of precious metals whether or not chemically defined	do.	79 r	100,000	51	89,100
Molybdenum:					
Ores and concentrates, including roasted and other, Mo content	do.	8,780	268,000	11,900	746,000
Chemicals, gross weight:					
Oxides and hydroxides	do.	822	15,800	1,240	42,500
Molybdates, all	do.	2,200	19,800	4,320	54,800
Orange	do.	1,030	4,760	983	4,780

See footnotes at end of table.

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TABLE 8—Continued

U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		2004		2005	
		Quantity	Value	Quantity	Value
Metals—Continued:					
Molybdenum—Continued:					
Ferromolybdenum, Mo content	metric tons	5,310	158,000	4,050	278,000
Other, includes powders, unwrought, bars and rods, waste and scrap, wire, other, gross weight	do.	896	34,300	879	72,900
Nickel, Ni content:					
Primary, chemicals and unwrought	do.	136,000	1,890,000	143,000	2,060,000
Secondary, stainless steel scrap and waste and scrap	do.	18,800	250,000	15,500	223,000
Wrought, not alloyed, bars, rods, profiles, wire, sheets, strip, foil, tubes, pipes	do.	797	20,300	1,060	26,000
Alloyed, unwrought ingot, bars, rods, profiles, wire, sheets, strip, foil, tubes, pipes, other alloyed articles	do.	19,900	349,000	23,300	481,000
Platinum-group metals, metal content:					
Platinum, grains and nuggets, sponge, other unwrought, other, waste and scrap, coins	do.	86,400	2,200,000	106,000	2,280,000
Palladium, unwrought and other	do.	127,000	931,000	139,000	855,000
Iridium, unwrought and other forms	kilograms	3,230	18,000	3,010	16,700
Osmium, unwrought	do.	75	421	39	362
Ruthenium, unwrought	do.	18,800	35,900	23,200	49,800
Rhodium, unwrought and other forms	do.	13,200	397,000	13,600	821,000
Rare earths, estimated equivalent rare-earth oxide (REO) content:					
Cerium compounds, including oxides, hydroxides, nitrates, sulfate chlorides, oxalates	do.	1,880,000	13,200 r	2,170,000	10,600
Yttrium compounds content by weight greater than 19% but less than 85% oxide equivalent	do.	136,000	3,510	223,000	3,480
Compounds, including oxides, hydroxides, nitrates, other compounds except chlorides	do.	11,400,000	64,100	8,550,000	59,600
Mixtures of REO's except cerium oxide	do.	1,660,000	4,930	640,000	6,320
Metals, whether intermixed or alloyed	do.	804,000	3,500	880,000	4,900
Mixtures of rare-earth chlorides, except cerium chloride	do.	1,310,000	6,870	2,670,000	6,330
Ferrocerium and other pyrophoric alloys	do.	105,000	1,770	130,000	2,050
Rhenium:					
Metal	do.	11,800	12,900	21,800	23,300
Ammonium perrhenate	do.	12,100	7,560	10,300	7,040
Selenium and tellurium:					
Selenium, Se content:					
Selenium	do.	402,000	16,000	575,000	33,900
Dioxide	do.	10,300	293	14,100	1,190
Tellurium, Te content	do.	62,800	2,620	42,200	4,650
Silicon, gross weight:					
Ferrosilicon	metric tons	247,000	201,000	290,000	215,000
Metal	do.	167,000	314,000	157,000	366,000
Silver:					
Ash and residues, Ag content	kilograms	6,710	1,530	2,630	769
Bullion, Ag content	do.	3,410,000	728,000	3,880,000	902,000
Dore, Ag content	do.	346,000	117,000	300,000	89,500
Metal powder, gross weight	do.	27,400	6,920	28,400	6,840
Nitrate, gross weight	do.	--	--	201	30
Ores and concentrates, Ag content	do.	2,220	1,410	433	318
Semimanufactured forms containing 99.5% or more by weight of silver, gross weight	do.	52,300	11,900	181,000	39,800
Waste and scrap, gross weight	do.	2,020,000	160,000	3,640,000	126,000
Unwrought, other, gross weight	do.	342,000	69,600	357,000	80,400
Thallium, unwrought powders, waste and scrap, other	do.	325	117	235	33
Thorium and thorium-bearing materials, compounds	do.	5,320	170	4,930	145
Tin, gross weight:					
Compounds	metric tons	635	6,030	564	5,720
Dross, skimmings, scrap, residues, alloys, n.s.p.f.	do.	5,790	24,500	9,930	28,500
Metal, unwrought	do.	47,600	390,000	37,500	285,000
Miscellaneous, includes tinfoil, tin powder, flitters, metallics, manufactures, n.s.p.f.	do.	NA	7,080	NA	8,010
Tinplate and terneplate	do.	328,000	215,000	391,000	300,000
Tinplate scrap	do.	9,650	2,020	16,800	3,160

See footnotes at end of table.

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TABLE 8—Continued
U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		2004		2005	
		Quantity	Value	Quantity	Value
Metals—Continued:					
Titanium:					
Concentrate:					
Ilmenite	metric tons	244,000	40,900	154,000	20,400
Rutile, natural and synthetic	do.	360,000	165,000	366,000	158,000
Metal:[3]					
Waste and scrap	do.	8,830	53,600	12,400	162,000
Unwrought	do.	11,900	79,900 r	15,800	120,000
Ingots	do.	1,530	14,800	2,450	38,700
Billets, bloom, sheet, bar, slab	do.	XX	XX	XX	XX
Powder	do.	142	2,840	126	4,060
Other	do.	959	8,350	1,330	22,900
Wrought products and castings, includes bar, castings, foil, pipe, plate, profile, rod, sheet, strip, tube, wire, other	do.	3,540 r	91,500	3,660	111,000
Ferrotitanium and ferrosilicon titanium	do.	6,940	21,200	16,900	76,700
Pigment, dioxide and oxide	do.	264,000	413,000	341,000	578,000
Titaniferous iron ore	do.	68,700	3,650	61,100	3,560
Titaniferous slag	do.	457,000	192,000	667,000	254,000
Tungsten, W content:					
Ammonium paratungstate	do.	2,090	16,500	1,920	29,900
Ferrotungsten and ferrosilicon tungsten	do.	392	3,510	385	5,390
Miscellaneous tungsten-bearing materials, metal powders, carbide powder, unwrought, waste and scrap, wrought, oxides, calcium tungstate, other tungstates, other compounds	do.	5,750	92,400	6,760	164,000
Ores and concentrates	do.	2,310	14,600	2,080	31,400
Vanadium:					
Aluminum-vanadium master alloy, gross weight	kilograms	19,100	67	1,010	15
Ferrovanadium, V content	do.	3,020,000 r	62,100	11,900,000	131,000
Metal, including waste and scrap, gross weight	do.	31,200	1,710	54,800	3,800
Miscellaneous chemicals, sulfates and vanadates, V content	do.	74,700 r	1,150 r	85,100	2,800
Pentoxide, anhydride, V content	do.	1,040,000 r	8,600	1,370,000	52,900
Vanadium-bearing ash, residues, slag from the manufacture of iron and steel, V_2O_5 content	do.	4,200,000 r	11,800	3,020,000	12,400
Other oxides and hydroxides, V content	do.	120,000 r	1,650	186,000	6,540
Zinc:					
Compounds, lithopone, chloride, compounds n.s.p.f., hydrosulfite, oxide, sulfate oxide, sulfate	metric tons	137,000	107,000	148,000	150,000
Ores and concentrates, Zn content	do.	231,000	98,700	156,000	117,000
Rolled	do.	2,500	9,250	3,630	11,900
Slab, refined	do.	812,000	888,000	668,000	875,000
Zirconium and hafnium:					
Hafnium, unwrought, including powders	do.	4	895	4	931
Zirconium:					
Ferrozirconium	do.	165	318	306	675
Ores and concentrates	do.	35,200	16,800	38,200	25,700
Oxide, includes germanium oxides and zirconium oxides	do.	3,690	33,000	3,160	33,300
Unwrought powder	do.	75 r	2,320	269	6,000
Waste and scrap	do.	722	45,600	755	64,900
Total		XX	69,000,000	XX	43,400,000
Industrial minerals:					
Abrasives, manufactured:					
Aluminum oxide, crude, ground and refined	do.	233,000 r	98,300 r	244,000	109,000
Metallic abrasives	do.	15,900	9,520	16,500	12,500
Silicon carbide, crude, ground and refined	do.	209,000	119,000	201,000	128,000
Asbestos:					
Chrysotile and other unspecified type	do.	3,450	806	2,530	1,420
Products with basis of asbestos, cellulose, or other minerals		NA	616,000	NA	580,000

See footnotes at end of table.

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TABLE 8—Continued

U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		2004		2005	
		Quantity	Value	Quantity	Value
Industrial minerals—Continued:					
Barite:					
Chemicals; chloride, oxide, hydroxide, peroxide, nitrate, precipitated carbonate	metric tons	18,200	14,600	14,100	16,600
Crude	do.	1,960,000	90,600	2,570,000	137,000
Ground	do.	5,100	700	84,000	8,250
Other sulfates	do.	33,800	17,800	28,600	16,000
Boron minerals and compounds:					
Borax		(2)	62	1	319
Boric acid		49	20,300	52	22,500
Colemanite		21	6,070	31	8,900
Ulexite		110	21,900	103	31,000
Bromine:					
Compounds, contained bromine	metric tons	6,600 r	13,800 r	6,830	16,800
Elemental	do.	2,840 r	2,070 r	2,710	3,990
Cement, hydraulic and clinker		27,300	1,140,000	33,700	1,560,000
Clays:					
China clay or kaolin	do.	205,000	38,600	262,000	40,200
Fire clay	do.	5,920	1,680	429	156
Decolorizing earths and fuller's earth	do.	227	48	2,460	286
Bentonite	do.	9,340	3,360	10,400	3,550
Common blue clay and other ball clay	do.	520	218	667	261
Other clay	do.	5,430	3,650	7,630	4,660
Chamotte or dina's earth	do.	2	2	3	9
Artifically activated clay and activated earth	do.	24,900	14,200	16,000	10,300
Diamond, industrial:					
Diamond stones, natural and miners'	thousand carats	1,780	13,800	2,120	29,500
Powder, dust and grit, natural and synthetic	do.	240,000	61,200	284,000	77,300
Diatomite	metric tons	1,710	488	4,480	1,280
Feldspar and nepheline syenite:					
Feldspar	do.	20,600	944	26,200	1,700
Nepheline syenite	do.	350,000	29,000	340,000	33,800
Fluorspar:					
Aluminum fluoride	do.	4,700	3,750	4,250	4,170
Cryolite	do.	3,860	3,660	3,110	3,260
Fluorspar	do.	599,000	95,300	629,000	122,000
Hydrofluoric acid, HF	do.	128,000	131,000	137,000	138,000
Garnet, industrial[e]		37	4,260	42	5,910
Gemstones		XX	15,500,000	XX	17,200,000
Graphite:					
Natural	metric tons	63,700	29,900	64,500	34,700
Electric furnace electrodes	do.	86,400	144,000	81,200	157,000
Gypsum:					
Crude		10,100	97,200	11,200	113,000
Plasters		5	3,420	6	4,350
Boards		617	87,100	739	129,000
Other		XX	43,200	XX	41,100
Iodine:					
Crude	metric tons	5,700	75,300	6,250	105,000
Potassium iodide	do.	678 r	11,500	458	9,970
Iron oxide pigments:					
Natural	do.	4,100	2,100	5,230	2,590
Synthetic	do.	166,000	114,000	188,000	138,000
Kyanite, andalusite, sillimanite	do.	4,010	1,420	6,300	2,410
Lime		232	25,900	310	33,000
Lithium chemicals:					
Carbonate	metric tons	15,400	26,500	18,900	27,500
Hydroxide	do.	64	233	124	453

See footnotes at end of table.

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TABLE 8—Continued

U.S. IMPORTS FOR CONSUMPTION OF PRINCIPAL MINERALS AND PRODUCTS, EXCLUDING MINERAL FUELS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

Mineral or product		2004		2005	
		Quantity	Value	Quantity	Value
Industrial minerals—Continued:					
Magnesium compounds:					
Compounds, chlorides, hydroxide, peroxide, sulfates	metric tons	132,000	40,600	119,000	34,800
Magnesite, crude and processed:					
Caustic-calcined magnesia	do.	157,000	22,200	152,000	23,900
Dead-burned and fused magnesia	do.	418,000	109,000	478,000	124,000
Other magnesia	do.	15,700	10,800	18,300	11,300
Crude	do.	15,900	1,980	15,000	2,260
Mica:					
Scrap and flake:					
Powder	do.	22,300	10,800	21,400	10,100
Waste	do.	1,420 r	659 r	900	365
Sheet:					
Unworked, excludes unworked sheet mica valued at less than $1 per kilogram	do.	124	358	53	202
Worked	do.	1,280	11,800	1,340	12,900
Nitrogen, major compounds, gross weight[3]		16,000	3,580,000	18,000	4,670,000
Peat moss	metric tons	786,000	159,000	891,000	195,000
Perlite, processed crude	do.	238,000	9,660	196,000	7,970
Phosphate rock and phosphatic materials		2,690	178,000	2,730	203,000
Potash, chloride, sulfate, nitrate, sodium nitrate mixtures	metric tons	8,140,000	751,000 r	8,110,000	1,170,000
Pumice:					
Crude or unmanufactured		401	31,400	239	31,800
Wholly or partially manufactured		1	3,660	1	5,750
Salt		11,900	159,000	12,100	180,000
Sand and gravel:					
Construction		4,760	56,900	7,160	86,800
Industrial		490	12,400	711	18,200
Silica, special stone products		NA	6,800	NA	7,700
Soda ash		6	1,880	8	2,460
Stone:					
Crushed, chips, calcium carbonate fines, excludes precipitated carbonates		18,600 r	179,000 r	21,000	194,000
Dimension		NA	1,790,000	NA	2,180,000
Strontium:					
Carbonate	metric tons	23,600	8,430	17,900	6,930
Celestite	do.	6,290	332	1,820	98
Metal	do.	217	1,070	770	2,210
Nitrate	do.	527	798	714	637
Oxide, hydroxide, peroxide	do.	98	76	9	38
Sulfur:					
Elemental		2,850 e	76,800	2,820 e	70,500
Sulfuric acid, 100% H_2SO_4	metric tons	2,400,000	104,000	2,680,000	122,000
Talc		226	58,400	237	55,600
Vermiculite[e]		69	13,000	91	17,000
Wollastonite[e]	metric tons	4,500	563	6,000	750
Total		XX	26,100,000	XX	30,600,000
Grand total		XX	95,100,000	XX	73,900,000

[e]Estimated. [r]Revised. NA Not available. XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

[3]Category regrouped in 2004; see commodity chapter for details.

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TABLE 9
WORLD AND U.S. PRODUCTION OF SELECTED NONFUEL MINERAL COMMODITIES[1]

(Thousand metric tons unless otherwise specified)

Mineral or product		World total					United States	
		2001	2002	2003	2004	2005	2005	Percentage of world total
Metals:								
Aluminum[2]		24,300	26,100	28,000 r	29,900 r	31,900	2,480	7.8
Antimony	metric tons	157,000	114,000 r	115,000 r	129,000 r	139,000	--	--
Arsenic trioxide[3]	do.	63,000 r	62,500 r	62,400 r	52,700 r	52,500	--	--
Bauxite[3, 4, 5]		137,000	144,000	153,000 r	160,000 r	169,000	NA	NA
Beryl[3]	metric tons	2,990	2,540	2,690 r	2,770 r	3,440	2,780	80.8
Bismuth, refinery	do.	5,820 r	6,730 r	8,740 r	10,500 r	11,900	--	--
Cadmium, refinery	do.	20,000 r	18,000 r	18,500	18,700 r	19,400	1,065	5.5
Chromite[3]		12,200 r	14,600 r	15,400 r	17,700 r	19,300	--	--
Cobalt, Co content:								
Mine	metric tons	44,800 r	50,600 r	50,800 r	57,100 r	57,900	--	--
Refinery	do.	38,700 r	40,800 r	43,800	49,100	54,900	--	--
Columbium (niobium)-tantalum concentrates[3]	do.	76,600	81,200	80,800	67,500 r	67,200	--	--
Copper:								
Mine		13,700	13,700	13,700	14,700 r	15,100	1,140	7.6
Refinery		15,700 r	15,500 r	15,300 r	15,900 r	16,600	1,260	7.6
Gold	kilograms	2,560,000	2,550,000	2,560,000 r	2,440,000 r	2,470,000	256,000	10.4
Iron ore[3]		1,050,000 r	1,100,000 r	1,220,000 r	1,360,000 r	1,530,000	54,400	3.5
Iron and steel:								
Direct-reduced iron[2]		39,000 r	43,700 r	45,300 r	48,000 r	49,200	220	0.4
Pig iron[2]		585,000	610,000	666,000 r	713,000 r	789,000	37,200	4.7
Raw steel		853,000	906,000	972,000	1,060,000 r	1,120,000	93,300	8.3
Lead:								
Mine	metric tons	3,050,000 r	2,840,000 r	3,140,000	3,110,000	3,270,000	426,000	13.0
Refinery	do.	6,600,000 r	6,780,000 r	6,780,000 r	6,950,000 r	7,470,000	1,280,000	17.2
Magnesium[5]	do.	420,000 r	440,000 r	485,000 r	595,000 r	626,000	W	NA
Manganese ore[3]		20,900	22,200	24,100	27,700 r	29,100	--	--
Mercury[5]	metric tons	1,500	1,490	1,370 r	1,890 r	1,680	NA	NA
Molybdenum, Mo content	do.	133,000 r	122,000 r	131,000 r	159,000 r	185,000	58,000	31.3
Nickel, Ni content:								
Mine	do.	1,350,000	1,350,000 r	1,370,000 r	1,400,000 r	1,480,000	--	--
Refinery	do.	1,190,000 r	1,200,000 r	1,220,000	1,270,000 r	1,300,000	--	--
Platinum-group metals	kilograms	410,000 r	430,000 r	465,000 r	492,000 r	515,000	17,200	3.3
Selenium[2, 5]	do.	1,420,000 r	1,370,000 r	1,440,000 r	1,330,000	1,390,000	W	NA
Silver	metric tons	18,700 r	18,800 r	18,800 r	19,800 r	20,200	1,230	6.1
Tellurium[2, 5]	kilograms	109,000	89,300	95,200	124,000 r	119,000	W	NA
Tin:								
Mine	metric tons	246,000 r	233,000 r	258,000 r	298,000 r	292,000	--	--
Smelter[6]	do.	289,000 r	280,000	280,000	309,000	349,000	11,800	3.4
Tungsten, W content	do.	50,800 r	66,100 r	68,200 r	69,400 r	70,100	--	--
Zinc:								
Mine	do.	8,930,000 r	8,550,000 r	9,470,000 r	9,460,000 r	9,800,000	748,000	7.6
Smelter		9,320 r	9,720 r	9,900 r	10,400 r	10,700	309	2.9
Industrial minerals:								
Asbestos	metric tons	2,060,000 r	2,320,000 r	2,360,000 r	2,360,000 r	2,400,000	--	--
Barite	do.	6,780,000 r	6,490,000 r	6,790,000 r	7,440,000 r	7,870,000	489,000 [7]	6.2
Boron minerals	do.	4,730,000	4,590,000 r	4,730,000 r	5,070,000 r	4,910,000	1,150,000 [7]	23.4
Bromine	thousand kilograms	509,000 r	503,000 r	488,000 r	544,000 r	555,000	226,000 [7]	40.8
Celesite	metric tons	399,000 r	435,000	471,000	457,000 r	494,000	--	--
Cement, hydraulic		1,740,000 r	1,850,000	2,030,000 r	2,190,000 r	2,310,000	100,900 [8]	4.4
Clays:								
Bentonite		10,400	10,300	10,500 r	11,500 r	11,700	4,710	40.3
Fuller's earth	metric tons	4,600,000	5,520,000 r	6,280,000 r	5,890,000 r	5,610,000	2,990,000	53.3
Kaolin		44,900 r	43,000 r	44,100 r	44,200 r	44,700	7,800	17.5
Diamond, natural	thousand carats	127,000	141,000 r	158,000 r	182,000 r	183,000	--	--
Diatomite	metric tons	2,000,000 r	1,950,000 r	1,950,000 r	1,950,000 r	2,020,000	653,000 [7]	32.3

See footnotes at end of table.

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TABLE 9—Continued

WORLD AND U.S. PRODUCTION OF SELECTED NONFUEL MINERAL COMMODITIES[1]

(Thousand metric tons unless otherwise specified)

Mineral or product		World total					United States	
		2001	2002	2003	2004	2005	2005	Percentage of world total
Industrial minerals—Continued:								
Feldspar		11,800 r	12,000 r	12,200 r	12,600 r	12,900	748	5.8
Fluorspar	metric tons	4,600,000 r	4,430,000 r	4,910,000 r	5,220,000 r	5,260,000	--	--
Graphite, natural	do.	816,000 r	932,000 r	999,000 r	1,020,000 r	1,050,000	--	--
Gypsum		105,000	107,000 r	110,000 r	112,000 r	118,000	21,100	17.9
Iodine, crude	thousand kilograms	20,700	21,000	22,900 r	24,800 r	25,400	1,570	6.2
Lime		121,000	120,000 r	125,000 r	127,000 r	127,000	20,000 [7, 8]	15.7
Magnesite, crude[5]		11,100	13,600	14,000	14,700 r	14,300	W	NA
Mica, including scrap and flake[9]	metric tons	368,000	269,000	271,000 r	319,000 r	294,000	78,100	26.6
Nitrogen, N content of ammonia		105,000	109,000	110,000	117,000	121,000	8,040 [10]	6.6
Peat		23,200 r	26,200 r	25,200 r	26,400 r	26,400	685	2.6
Perlite	metric tons	1,730,000	1,810,000 r	1,810,000 r	1,860,000 r	1,950,000	508,000 [7]	26.1
Phosphate rock[3]		126,000	135,000	138,000 r	141,000	147,000	36,100	24.5
Potash, K_2O equivalent		26,400	26,800 r	28,400	30,400 r	31,100	1,200	3.9
Pumice		15,600 r	16,200 r	16,600 r	17,700 r	17,500	1,270 [7]	7.2
Salt		214,000 r	212,000 r	218,000 r	229,000 r	238,000	45,200 [8]	19.0
Sand and gravel, industrial, silica		113,000 r	113,000	115,000 r	117,000 r	118,000	30,600 [7]	25.9
Soda ash, natural and manufactured		35,700 r	37,200 r	38,400 r	40,300 r	41,900	11,000 [11]	26.2
Sulfur, all forms		61,400 r	62,600 r	64,200 r	66,000 r	66,000	9,460	14.3
Talc and pyrophyllite[12]	metric tons	8,780,000 r	7,590,000 r	8,100,000 r	8,230,000 r	8,250,000	856,000	10.4
Titanium concentrates:[3]								
Ilmenite and leucoxene	do.	5,130,000 r	5,470,000 r	5,720,000 r	5,640,000	5,840,000	500,000 [13]	8.6
Rutile[5]	do.	421,000	446,000	361,000	354,000 r	369,000	(14)	NA
Vermiculite	do.	431,000	497,000 r	491,000	516,000 r	527,000	100,000	19.0

rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data; not included in "World" total. -- Zero.

[1]Data are rounded to no more than three significant digits.

[2]Primary.

[3]Gross weight.

[4]Individual country figures that are included in the world total represent dried bauxite equivalent of crude ore, but for some countries available data are insufficient to permit this adjustment.

[5]"World total" for years listed does not include U.S. production.

[6]Includes tin content of alloys made directly from ore.

[7]Quantity sold or used by producers.

[8]Includes Puerto Rico.

[9]Excludes, if any, U.S. production of low-quality sericite and sheet mica.

[10]Synthetic anhydrous ammonia; excludes coke oven byproduct ammonia.

[11]U.S. production is natural only.

[12]Data for the United States exclude proprietary pyrophyllite production.

[13]Includes rutile to avoid disclosing company proprietary data. Rounded to one significant digit.

[14]Included with ilmenite to avoid disclosing company proprietary data; not included in "Total."

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Mining and Quarrying Trends

By Mary E. Ewell

Domestic survey data were prepared by the author and each of the statistical assistants who has responsibility for the mineral commodities indicated.

The mining and quarrying trends shown in this report were calculated from nonfuel mineral data reported to the U.S. Geological Survey (USGS) by mining and quarrying companies operating in the United States. The data for 2005 were reported on the "Mine, Development, and Mineral Exploration Supplement" statistical survey conducted by the USGS and on the production surveys for some more widely produced nonfuel mineral commodities, such as sand and gravel. Additional data for 2005 were derived from annual USGS production and consumption surveys of nonfuel mineral producers; these surveys covered 58 nonfuel mineral commodities produced in the United States. Nonfuel minerals exclude coal, petroleum coke, and related products.

The data in the following tables are reported according to the primary product of a mine or operation; a product of lesser value is considered to be a byproduct. The primary product is the product with the highest total value for the year. In some instances, the values of two products at the same operation are so similar that the products are coproducts.

Total domestic mining and waste removal for nonfuel mineral materials production amounted to 6.0 billion metric tons (Gt) in 2005, a 2% increase compared with that of 2004. These materials included 4.5 Gt of crude ore mined or quarried and 1.4 Gt of mine ore and waste from development operations. Of the nonfuel mineral materials mined, 62% was for the production of industrial minerals, and 38% was for the production of metals. Overall, 97% of nonfuel minerals was mined and quarried using surface methods, and 3% was mined underground.

Total surface mining, quarrying, and waste removal for industrial minerals production amounted to 3.5 Gt, a 4% increase compared with the revised figure for 2004. Crude ore mined at these surface operations was 3.2 Gt, and 369 million metric tons (Mt) was ore and waste from development operations. Underground mining for industrial minerals was only 138 Mt, nearly all of which was crude ore.

Total surface mining and waste removal for metal ores amounted to 2.3 Gt, about the same level as that of 2004. Of the 2.3 Gt, 1.2 Gt was crude ore mined, and 1.1 Gt was ore and waste from development operations. Underground mining of metal ores amounted to only 20 Mt, of which 95% was crude ore.

The major States in which mining for nonfuel minerals took place, in order of total material handled, were Nevada, Arizona, Florida, Minnesota, California, Texas, Michigan, Utah, Ohio, and Pennsylvania. These 10 States accounted for 60% of the tonnage removed in the production of nonfuel minerals mined in the United States. Nearly all nonfuel mine production in these States was from surface operations.

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TABLE 1

MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES, BY TYPE[1]

(Million metric tons)

	Surface[2]			Underground[3]			All mines		
Type of ore and year	Crude ore	Waste[4]	Total	Crude ore	Waste[4]	Total	Crude ore	Waste[4]	Total
Metals:									
2001	1,080	1,120	2,200	17	3	20	1,100	1,120	2,220
2002	1,060	1,020	2,080	15	3	18	1,070	1,020	2,090
2003	1,080 r	1,020	2,090 r	14	1	15	1,090 r	1,020	2,110 r
2004	1,190 r	1,060	2,250 r	14	2	16	1,200 r	1,060	2,260 r
2005	1,210	1,050	2,260	19	1	20	1,230	1,050	2,280
Industrial minerals:									
2001	2,840	358	3,200	114	(5)	114	2,960	358	3,310
2002	2,850	442	3,290	108	(5)	108	2,960	442	3,400
2003	2,900	416	3,310	107	(5)	107	3,000	416	3,420
2004	3,000 r	409	3,410 r	139 r	(5)	139 r	3,140 r	409	3,550 r
2005	3,160	369	3,530	137	1	138	3,300	370	3,670
All mineral commodities:									
2001	3,920	1,480	5,400	131	4	135	4,050	1,480	5,530
2002	3,910	1,460	5,370	123	3	126	4,030	1,460	5,490
2003	3,980 r	1,430	5,410 r	121	2	123	4,100 r	1,430	5,530 r
2004	4,190 r	1,470	5,650 r	153 r	2	155 r	4,340 r	1,470	5,810 r
2005	4,380	1,420	5,790	156	2	158	4,530	1,420	5,950

rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes materials from wells, ponds, and pumping operations.

[3]Includes solution mining.

[4]Includes ore and waste from development operations.

[5]Less than ½ unit.

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TABLE 2

MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 2005, BY COMMODITY AND STATE[1]

Commodity or State	Number of mines[2]	Surface[3] Crude ore (thousand metric tons)	Surface[3] Waste[4] (thousand metric tons)	Surface[3] Total (thousand metric tons)	Underground[5] Crude ore (thousand metric tons)	Underground[5] Waste[4] (thousand metric tons)	Underground[5] Total (thousand metric tons)	All mines Crude ore (thousand metric tons)	All mines Waste[4] (thousand metric tons)	All mines Total (thousand metric tons)
Commodity:										
Metal ore:	44	226,000	774,000	1,000,000	4,860	1,030	5,900	231,000	775,000	1,010,000
Gold	9	176,000	155,000	331,000	--	--	--	176,000	155,000	331,000
Iron	43	813,000	120,000	933,000	13,900	383	14,200	826,000	121,000	947,000
Other[6]	96	1,210,000	1,050,000	2,260,000	18,700	1,420	20,100	1,230,000	1,050,000	2,280,000
Total										
Industrial minerals:	5	742	W	742 [7]	--	--	--	742	W	742 [7]
Barite	638	41,700	36,300	78,000	--	--	--	41,700	36,300	78,000
Clays	11	653	W	653 [7]	--	--	--	653	W	653 [7]
Diatomite	12	1,450	--	1,450	--	--	--	1,450	--	1,450
Feldspar[8]	45	19,300	3,020	22,300	1,850	--	1,850	21,100	3,020	24,100
Gypsum	15	151,000	W	151,000 [7]	--	--	--	151,000	W	151,000 [7]
Phosphate rock	16	1,270	717	1,990	--	--	--	1,270	717	1,990
Pumice[9]	67	7,120	--	7,120	34,200	--	34,200	41,300	--	41,300
Salt										
Sand and gravel:	9,975	1,270,000	--	1,270,000	--	--	--	1,270,000	--	1,270,000
Construction	136	29,900	--	29,900	W	--	W	29,900 [10]	--	29,900 [10]
Industrial	6	--	--	--	11,000	--	11,000	11,000	--	11,000
Soda ash										
Stone:	3,171	1,610,000	126,000	1,730,000	77,200	535	77,700	1,690,000	127,000	1,810,000
Crushed	154	1,510	W	1,510 [7]	W	--	W	1,510 [10]	W	1,510 [7, 10]
Dimension	13	661	2,430	3,090	--	--	--	661	2,430	3,090
Talc and pyrophyllite	85	23,700	200,000	224,000	13,100	--	13,100	36,800	200,000	237,000
Other[11]	14,349	3,160,000	369,000	3,530,000	137,000	535	138,000	3,300,000	370,000	3,670,000
Total	14,445	4,380,000	1,420,000	5,790,000	156,000	1,950	158,000	4,530,000	1,420,000	5,950,000
Grand total										
State:										
Alabama	188	66,700	6,040	72,700	W	W	W	66,700 [10]	6,040 [10]	72,700 [10]
Alaska	175	25,800	41,900	67,800	W	W	W	25,800 [10]	41,900 [10]	67,800 [10]
Arizona	430	499,000	97,200	596,000	--	--	--	499,000	97,200	596,000
Arkansas	141	47,800	5,930	53,700	W	--	W	47,800 [10]	5,930	53,700 [10]
California	853	226,000	W	226,000 [7]	W	W	W	226,000 [10]	W	226,000 [7, 10]
Colorado	412	76,100	30,700	107,000	W	W	W	76,100 [10]	30,700 [10]	107,000 [10]
Connecticut	98	18,300	881	19,200	--	--	--	18,300	881	19,200
Delaware	14	3,790	W	3,790 [7]	--	--	--	3,790	W	3,790 [7]
Florida	193	283,000	W	283,000 [7]	--	--	--	283,000	W	283,000 [7]
Georgia	242	98,900	15,200	114,000	1,450	10	1,460	100,000	15,200	116,000
Hawaii	31	7,560	493	8,060	--	--	--	7,560	493	8,060
Idaho	380	37,500	W	37,500 [7]	W	W	W	37,500 [10]	W	37,500 [7, 10]
Illinois	274	114,000	5,940	120,000	4,850	34	4,890	118,000	5,970	124,000
Indiana	261	83,200	5,220	88,400	3,040	17	3,060	86,200	5,240	91,500
Iowa	388	50,800	3,000	53,800	5,730	33	5,770	56,500	3,040	59,600
Kansas	364	32,900	2,310	35,200	3,120	4	3,120	36,000	2,310	38,300
Kentucky	128	48,300	3,930	52,200	22,600	158	22,800	70,900	4,090	75,000
Louisiana	147	27,500	980	28,500	13,400	--	13,400	40,900	980	41,900
Maine	197	15,100	405	15,500	--	--	--	15,100	405	15,500
Maryland	86	45,500	2,920	48,400	W	W	W	45,500 [10]	2,920 [10]	48,400 [10]
Massachusetts	142	29,400	1,130	30,500	--	--	--	29,400	1,130	30,500
Michigan	559	141,000	W	141,000 [7]	1,920	--	1,920	143,000	W	143,000 [7]
Minnesota	614	203,000	121,000	324,000	--	--	--	203,000	121,000	324,000
Mississippi	120	19,200	1,390	20,600	W	W	W	19,200 [10]	1,390 [10]	20,600 [10]
Missouri	291	84,700	6,910	91,600	W	W	W	84,700 [10]	6,910 [10]	91,600 [10]
Montana	273	40,800	W	40,800 [7]	1,800	W	1,800 [7]	42,600	W	42,600 [7]
Nebraska	174	19,100	519	19,600	W	W	W	19,100 [10]	519 [10]	19,600 [10]
Nevada	895	504,000	601,000	1,100,000	W	W	W	504,000 [10]	601,000 [10]	1,100,000 [10]
New Hampshire	99	13,500	425	13,900	--	--	--	13,500	425	13,900

See footnotes at end of table.

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TABLE 2—Continued

MATERIAL HANDLED AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 2005, BY COMMODITY AND STATE[1]

Commodity or State	Number of mines[2]	Surface[3] Crude ore (thousand metric tons)	Surface[3] Waste[4] (thousand metric tons)	Surface[3] Total (thousand metric tons)	Underground[5] Crude ore (thousand metric tons)	Underground[5] Waste[4] (thousand metric tons)	Underground[5] Total (thousand metric tons)	All mines Crude ore (thousand metric tons)	All mines Waste[4] (thousand metric tons)	All mines Total (thousand metric tons)
State—Continued:										
New Jersey	95	45,800	1,890	47,700	--	--	--	45,800	1,890	47,700
New Mexico	536	54,800	W	54,800 [7]	12,200	--	12,200	67,100	W	67,100 [7]
New York	625	83,400	4,970	88,400	6,770	W	6,770 [7]	90,200	4,970 [10]	95,200 [7, 10]
North Carolina	241	97,100	10,900	108,000	--	--	--	97,100	10,900	108,000
North Dakota	172	11,400	W	11,400 [7]	--	--	--	11,400	W	11,400 [7]
Ohio	380	128,000	7,080	136,000	W	--	W	128,000 [10]	7,080	136,000 [10]
Oklahoma	163	63,000	4,380	67,400	W	W	W	63,000 [10]	4,380 [10]	67,400 [10]
Oregon	311	48,000	2,640	50,600	--	--	--	48,000	2,640	50,600
Pennsylvania	341	116,000	8,420	124,000	3,670	26	3,690	119,000	8,450	128,000
Rhode Island	28	4,310	129	4,440	--	--	--	4,310	129	4,440
South Carolina	116	48,000	4,040	52,000	--	--	--	48,000	4,040	52,000
South Dakota	256	21,600	15,800	37,500	--	--	--	21,600	15,800	37,500
Tennessee	201	68,700	5,770	74,500	3,020	W	3,020 [7]	71,700	5,770 [10]	77,500 [7, 10]
Texas	504	219,000	13,300	233,000	5,120	W	5,120 [7]	224,000	13,300 [10]	238,000 [7, 10]
Utah	391	94,500	W	94,500 [7]	631	W	631 [7]	95,200	W	95,200 [7]
Vermont	111	10,700	472	11,200	--	--	--	10,700	472	11,200
Virginia	204	99,000	8,280	107,000	W	W	W	99,000 [10]	8,280 [10]	107,000 [10]
Washington	332	60,300	1,180	61,500	W	--	W	60,300 [10]	1,180	61,500 [10]
West Virginia	49	13,200	1,150	14,400	2,750	W	2,750 [7]	16,000	1,150 [10]	17,100
Wisconsin	713	84,100	3,240	87,400	W	W	W	84,100 [10]	3,240 [10]	87,400 [10]
Wyoming	507	23,300	4,260	27,500	9,930	--	9,930	33,200	4,260	37,400
Undistributed[12]	--	118,000	364,000	482,000	53,900	1,670	55,500	172,000	366,000	538,000
Total	14,445	4,380,000	1,420,000	5,790,000	156,000	1,950	158,000	4,530,000	1,420,000	5,950,000

W Withheld to avoid disclosing company proprietary data; included with "Other" or "Undistributed." -- Zero.

[1]Data are rounded to no more than three significant digits except "number of mines"; may not add to totals shown.

[2]Includes quarries and other mineral operations.

[3]Includes materials from wells, ponds, and pumping operations.

[4]Includes ore and waste from development operations.

[5]Includes solution mining.

[6]Includes beryllium, copper, gold-silver, lead, lead-zinc, magnesium metal, molybdenum, platinum and palladium, silver, titanium, uranium, and zinc.

[7]Excludes waste from mining operations and ore and waste from development operations.

[8]Includes aplite.

[9]Excludes volcanic cinder and scoria; included with "Crushed stone."

[10]Excludes materials from underground operations.

[11]Includes abrasives, boron minerals, bromine, garnet, greensand marl, iodine, iron oxide pigments, kyanite, lithium minerals, magnesite, magnesium compounds, mica, olivine, perlite, potash, tripoli, vermiculite, wollastonite, zeolites, and industrial minerals indicated by symbol W.

[12]Includes States indicated by symbol W.

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TABLE 3

VALUE OF PRINCIPAL MINERAL PRODUCTS AND BYPRODUCTS OF SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 2005[1]

(Dollars per metric ton)

Commodity	Surface			Underground			All mines		
	Principal mineral product	Byproduct	Total	Principal mineral product	Byproduct	Total	Principal mineral product	Byproduct	Total
Metal ore:									
Gold	13.88	1.10	14.98	W	W	W	13.88 [2]	1.10 [2]	14.98 [2]
Iron	18.32	--	18.32	--	--	--	18.32	--	18.32
Average, metals[3]	11.82	0.97	12.79	60.89	16.91	77.80	12.82	1.29	14.11
Industrial minerals:									
Barite	28.28	--	28.28	--	--	--	28.28	--	28.28
Clays	39.66	--	39.66	--	--	--	39.66	--	39.66
Feldspar[4]	25.90	W	25.90 [5]	--	--	--	25.90	W	25.90 [5]
Gypsum	6.93	--	6.93	9.45	--	9.45	7.26	--	7.26
Phosphate rock	7.06	--	7.06	--	--	--	7.06	--	7.06
Pumice[6]	27.80	--	27.80	--	--	--	27.80	--	27.80
Salt	72.05	--	72.05	19.13	--	19.13	27.21	--	27.21
Sand and gravel:									
Construction	5.86	--	5.86	--	--	--	5.86	--	5.86
Industrial	24.79	--	24.79	W	--	W	24.79 [2]	--	24.79 [2]
Soda ash	--	--	--	88.39	--	88.39	88.39	--	88.39
Stone:									
Crushed	7.16	--	7.16	7.63	--	7.63	7.18	--	7.18
Dimension	177.89	--	177.89	W	--	W	177.89 [2]	--	177.89 [2]
Talc and pyrophyllite	30.81	--	30.81	--	--	--	30.81	--	30.81 [2]
Average, industrial minerals[7]	7.88	0.02	7.90	19.31	--	19.31	8.38	0.02	8.40
Average, industrial minerals, excluding sand and gravel and stone[7]	20.84	0.21	21.05	33.06	--	33.06	23.53	0.16	23.69
Average, metals and industrial minerals[3,7]	8.76	0.23	8.99	24.17	1.98	26.15	9.35	0.30	9.65
Average, metals and industrial minerals, excluding sand and gravel and stone[3,7]	13.65	0.81	14.46	39.33	3.81	43.14	15.41	1.02	16.43

W Withheld to avoid disclosing company proprietary data; included in appropriate "Average." -- Zero.

[1]Values calculated from unrounded data; may not add to totals shown because of independent rounding.

[2]Value of products at surface operations only.

[3]Includes values of beryllium, copper, gold-silver, lead, lead-zinc, magnesium metal, molybdenum, platinum and palladium, silver, titanium, zinc, and metals indicated by symbol W.

[4]Includes aplite.

[5]Value of principal mineral product only.

[6]Excludes volcanic cinder and scoria; included with "Crushed stone."

[7]Includes values of abrasives, boron minerals, bromine, diatomite, garnet, greensand marl, iodine, iron oxide pigments, kyanite, lithium minerals, magnesite, magnesium compounds, mica, olivine, perlite, potash, tripoli, vermiculite, wollastonite, zeolites, and industrial minerals indicated by symbol W.

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TABLE 4
TWENTY-FIVE LEADING METAL AND INDUSTRIAL MINERAL MINES AND QUARRIES IN THE UNITED STATES IN 2005, IN ORDER OF OUTPUT OF CRUDE ORE[1]

Name of mine, quarry or operation[2]	State	Operator	Commodity	Mining method
Metal:				
Morenci	Arizona	Phelps Dodge Corp.	Copper	Open pit.
Newmont Nevada operations[3]	Nevada	Newmont Mining Corporation	Gold	Open pit and stoping.
Betze-Post	do.	Barrick Gold Corporation	do.	Open pit and underground.
Chino	New Mexico	Phelps Dodge Corp.	Copper-molybdenum	Open pit.
Bagdad	Arizona	do.	do.	Do.
Sierrita	do.	do.	do.	Do.
Minntac	Minnesota	United States Steel Corporation	Iron ore	Do.
Bingham Canyon	Utah	Kennecott Utah Copper Corp.	Copper-molybdenum	Do.
Marigold	Nevada	Glamis Gold Ltd.	Gold	Do.
Ray	Arizona	ASARCO Incorporated	Copper	Do.
Cortez	Nevada	Placer Dome Inc.	Gold	Do.
Hibbing Taconite	Minnesota	Cleveland-Cliffs Inc	Iron ore	Do.
Round Mountain	Nevada	Round Mountain Gold Corp.	Gold	Do.
Tyrone	New Mexico	Phelps Dodge Corp.	Copper	Do.
Tilden	Michigan	Cleveland-Cliffs Inc	Iron ore	Do.
Keewatin Taconite	Minnesota	United States Steel Corporation	do.	Do.
Cresson	Colorado	Cripple Creek & Victor Gold Mining Co.	Gold	Do.
Empire	Michigan	Cleveland-Cliffs Inc	Iron ore	Do.
Continental Pit	Montana	Montana Resources	Copper-molybdenum	Do.
United Taconite	Minnesota	Cleveland-Cliffs Inc	Iron ore	Do.
Northshore	do.	do.	do.	Do.
Robinson	Nevada	Quadra Mining Ltd.	Copper-molybdenum	Do.
Fort Knox	Alaska	Kinross Gold Corporation	Gold	Do.
Mission Complex	Arizona	ASARCO Incorporated	Copper	Do.
Minorca	Minnesota	Mittal Steel Corporation	Iron ore	Do.
Industrial mineral:				
Florida mines (seven)	Florida	The Mosaic Company	Phosphate rock	Do.
South Pasture	do.	CF Industries, Inc.	do.	Do.
Swift Creek	do.	PCS Phosphate Co., Inc.	do.	Do.
White Rock	do.	Vecellio & Grogan, Inc.	Stone, crushed	Quarry.
F.E.C. Quarry	do.	Rinker Materials Corporation	do.	Do.
Aurora	North Carolina	PCS Phosphate Co., Inc.	Phosphate rock	Open pit.
Georgetown	Texas	Texas Crushed Stone Co., Inc.	Stone, crushed	Quarry.
Balcones Plant	do.	Cemex, Inc.	do.	Do.
Pennsuco Quarry	Florida	Titan Atlantic LLC	do.	Do.
McCook 378	Illinois	Vulcan Materials Co.	do.	Do.
Mosaic Potash Carlsbad	New Mexico	The Mosaic Company	Potash	Stoping.
Alico Quarry	Florida	Rinker Materials Corporation	Stone, crushed	Quarry.
Thornton Quarry	Illinois	Material Service Corporation	do.	Do.
Ste. Genevieve Quarry	Missouri	Tower Rock Stone Co.	do.	Do.
Stoneport Quarry	Michigan	Lafarge North America, Inc.	do.	Do.
Great Salt Lake Plant	Utah	Great Salt Lake Minerals Corporation	Potash	Pumping/solar evaporation.
OMYA California, Inc.	California	OMYA Industries, Inc.	Stone, crushed	Quarry.
Servtex	Texas	Hanson Building Materials America	do.	Do.
Dupont Pit	Washington	California Portland Cement Co.	Sand and gravel, construction	Open pit.
TXI Mill Creek Quarry	Oklahoma	Texas Industries, Inc.	Stone, crushed	Quarry.
Krome Quarry	Florida	Rinker Materials Corporation	do.	Do.
Hunter Quarry	Texas	Colorado Materials, Ltd.	do.	Do.
PBA Quarry	Florida	Palm Beach Aggregates, Inc.	do.	Do.
Port Inland	Michigan	O-N Minerals Co.	do.	Do.
Macon Quarry	Georgia	Rinker Materials Corporation	do.	Do.

[1]List includes private-sector operations only; excludes U.S. Bureau of Land Management and U.S. Forest Service operations.
[2]Where data are not reported for individual mining operations, ranking is on the basis of production as reported for a group of operations.
[3]Includes Carlin Mines complex, Lone Tree complex, Midas Mine, Twin Creeks Mine, and Turquoise Ridge Mine; ore was mined from 13 open pits and 4 underground mines.

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TABLE 5

TWENTY-FIVE LEADING METAL AND INDUSTRIAL MINERAL MINES AND QUARRIES IN THE UNITED STATES IN 2005, IN ORDER OF OUTPUT OF TOTAL MATERIAL HANDLED[1]

Name of mine, quarry or operation[2]	State	Operator	Commodity	Mining method
Metal:				
Betze-Post	Nevada	Barrick Gold Corporation	Gold	Open pit and underground.
Newmont Nevada operations[3]	do.	Newmont Mining Corporation	do.	Open pit and stoping.
Morenci	Arizona	Phelps Dodge Corp.	Copper	Open pit.
Bingham Canyon	Utah	Kennecott Utah Copper Corp.	Copper-molybdenum	Do.
Bagdad	Arizona	Phelps Dodge Corp.	do.	Do.
Minntac	Minnesota	United States Steel Corporation	Iron ore	Do.
Marigold	Nevada	Glamis Gold Ltd.	Gold	Do.
Hibbing Taconite	Minnesota	Cleveland-Cliffs Inc	Iron ore	Do.
Ray	Arizona	ASARCO Incorporated	Copper	Do.
Robinson	Nevada	Quadra Mining Ltd.	Copper-molybdenum	Do.
Chino	New Mexico	Phelps Dodge Corp.	do.	Do.
Sierrita	Arizona	do.	do.	Do.
Cortez	Nevada	Placer Dome Inc.	Gold	Do.
Fort Knox	Alaska	Kinross Gold Corporation	do.	Do.
Cresson	Colorado	Cripple Creek & Victor Gold Mining Co.	do.	Do.
Round Mountain	Nevada	Round Mountain Gold Corp.	do.	Do.
Tilden	Michigan	Cleveland-Cliffs Inc	Iron ore	Do.
Mission Complex	Arizona	ASARCO Incorporated	Copper	Do.
Keewatin Taconite	Minnesota	United States Steel Corporation	Iron ore	Do.
Empire	Michigan	Cleveland-Cliffs Inc	do.	Do.
Golden Sunlight	Montana	Placer Dome Inc.	Gold	Do.
United Taconite	Minnesota	Cleveland-Cliffs Inc	Iron ore	Do.
Tyrone	New Mexico	Phelps Dodge Corp.	Copper	Do.
Northshore	Minnesota	Cleveland-Cliffs Inc	Iron ore	Do.
Montana Tunnels	Montana	Apollo Gold Corp.	Gold	Do.
Industrial mineral:				
Florida mines (seven)	Florida	The Mosaic Company	Phosphate rock	Do.
Boron Mine	California	U.S. Borax, Inc.	Boron	Do.
South Pasture	Florida	CF Industries, Inc.	Phosphate rock	Do.
Swift Creek	do.	PCS Phosphate Co., Inc.	do.	Do.
White Rock	do.	Vecellio & Grogan, Inc.	Stone, crushed	Quarry.
F.E.C. Quarry	do.	Rinker Materials Corporation	do.	Do.
Aurora	North Carolina	PCS Phosphate Co., Inc.	Phosphate rock	Open pit.
Georgetown	Texas	Texas Crushed Stone Co., Inc.	Stone, crushed	Quarry.
Balcones Plant	do.	Cemex, Inc.	do.	Do.
Pennsuco Quarry	Florida	Titan Atlantic LLC	do.	Do.
McCook 378	Illinois	Vulcan Materials Co.	do.	Do.
Alico Quarry	Florida	Rinker Materials Corporation	do.	Do.
Thornton Quarry	Illinois	Material Service Corporation	do.	Do.
Ste. Genevieve Quarry	Missouri	Tower Rock Stone Co.	do.	Do.
Mosaic Potash Carlsbad	New Mexico	The Mosaic Company	Potash	Stoping.
Stoneport Quarry	Michigan	Lafarge North America, Inc.	Stone, crushed	Quarry.
OMYA California, Inc.	California	OMYA Industries, Inc.	do.	Do.
Servtex	Texas	Hanson Building Materials America	do.	Do.
TXI Mill Creek Quarry	Oklahoma	Texas Industries, Inc.	do.	Do.
Great Salt Lake Plant	Utah	Great Salt Lake Minerals Corporation	Potash	Pumping/solar evaporation.
Krome Quarry	Florida	Rinker Materials Corporation	Stone, crushed	Quarry.
Dupont Pit	Washington	California Portland Cement Co.	Sand and gravel, construction	Open pit.
Hunter Quarry	Texas	Colorado Materials, Ltd.	Stone, crushed	Quarry.
PBA Quarry	Florida	Palm Beach Aggregates, Inc.	do.	Do.
Port Inland	Michigan	O-N Minerals Co.	do.	Do.

[1]List includes private-sector operations only; excludes U.S. Bureau of Land Management and U.S. Forest Service operations.

[2]Where data are not reported for individual mining operations, ranking is on the basis of production as reported for a group of operations.

[3]Includes Carlin Mines complex, Lone Tree complex, Midas Mine, Twin Creeks Mine, and Turquoise Ridge Mine; ore was mined from 13 open pits and 4 underground mines.

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TABLE 6
MARKETABLE PRODUCT AND ORE TREATED OR SOLD AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 2005, BY SELECTED COMMODITY AND STATE[1]

(Thousand metric tons)

	Marketable product			Ore treated or sold		
Commodity or State	Surface	Underground	Total	Surface	Underground	Total
Commodity:						
Metal ore:						
Gold	W	W	W	201,000	4,860	206,000
Iron ore, usable	53,200	--	53,200	129,000	--	129,000
Industrial minerals:						
Barite	W	--	W	621	--	621
Clays	41,700	--	41,700	41,700	--	41,700
Diatomite	653	--	653	653	--	653
Feldspar[2]	1,450	--	1,450	1,450	--	1,450
Gypsum	19,300	1,850	21,100	19,300	1,850	21,100
Phosphate rock	36,100	--	36,100	151,000	--	151,000
Pumice[3]	1,270	--	1,270	1,270	--	1,270
Salt	(4)	43,800	43,800	(5)	45,600	45,600
Sand and gravel:						
Construction	1,270,000	--	1,270,000	1,270,000	--	1,270,000
Industrial	29,900	W	29,900	29,900	W	29,900
Soda ash	--	11,000	11,000	--	11,000	11,000
Stone:						
Crushed	1,610,000	77,200	1,690,000	1,610,000	77,200	1,690,000
Dimension	1,510	(6)	1,510	1,500	(7)	1,500
Talc and pyrophyllite	661	--	661	661	--	661
State:						
Alabama	69,200	(6)	69,200	69,200	(7)	69,200
Alaska	11,800	(6)	11,800	33,900	(7)	33,900
Arizona	98,500	--	98,500	499,000	--	499,000
Arkansas	49,400	(6)	49,400	49,400	(7)	49,400
California	225,000	(6)	225,000	230,000	(7)	230,000
Colorado	58,700	(6)	58,700	79,100	(7)	79,100
Connecticut	18,500	--	18,500	18,500	--	18,500
Delaware	3,790	--	3,790	3,790	--	3,790
Florida	178,000	--	178,000	285,000	--	285,000
Georgia	100,000	1,450	102,000	100,000	1,450	102,000
Hawaii	7,560	--	7,560	7,560	--	7,560
Idaho	29,000	(6)	29,000	38,000	(7)	38,000
Illinois	114,000	4,850	119,000	114,000	4,850	119,000
Indiana	87,500	(6)	87,500	87,500	(7)	87,500
Iowa	51,800	5,730	57,500	51,800	5,730	57,500
Kansas	33,500	3,110	36,600	33,500	3,110	36,600
Kentucky	48,300	22,600	70,900	48,300	22,600	70,900
Louisiana	27,300	12,900	40,100	28,000	13,600	41,600
Maine	15,700	--	15,700	15,700	--	15,700
Maryland	45,800	(6)	45,800	45,800	(7)	45,800
Massachusetts	29,800	--	29,800	29,800	--	29,800
Michigan	116,000	1,630	118,000	141,000	1,830	143,000
Minnesota	107,000	--	107,000	155,000	--	155,000
Mississippi	19,200	--	19,200	19,200	--	19,200
Missouri	112,000	(6)	112,000	84,900	31,500	116,000
Montana	17,900	(6)	17,900	43,000	(7)	43,000
Nebraska	21,400	(6)	21,400	25,400	(7)	25,400
Nevada	64,700	(6)	64,700	235,000	(7)	235,000
New Hampshire	13,500	--	13,500	13,500	--	13,500
New Jersey	45,900	--	45,900	47,700	--	47,700
New Mexico	22,600	(6)	22,600	55,600	(7)	55,600
New York	83,700	6,780	90,500	83,900	6,780	90,700
North Carolina	92,000	--	92,000	98,300	--	98,300

See footnotes at end of table.

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TABLE 6—Continued
MARKETABLE PRODUCT AND ORE TREATED OR SOLD AT SURFACE AND UNDERGROUND MINES IN THE UNITED STATES IN 2005, BY SELECTED COMMODITY AND STATE[1]

(Thousand metric tons)

Commodity or State	Marketable product			Ore treated or sold		
	Surface	Underground	Total	Surface	Underground	Total
State—Continued:						
North Dakota	11,400	--	11,400	11,400	--	11,400
Ohio	133,000	(6)	133,000	133,000	(7)	133,000
Oklahoma	63,100	(6)	63,100	63,100	(7)	63,100
Oregon	48,700	--	48,700	48,700	--	48,700
Pennsylvania	116,000	3,670	120,000	116,000	3,670	119,000
Rhode Island	4,310	--	4,310	4,310	--	4,310
South Carolina	47,900	--	47,900	48,000	--	48,000
South Dakota	19,700	--	19,700	21,900	--	21,900
Tennessee	71,800	(6)	71,800	71,800	(7)	71,800
Texas	231,000	(6)	231,000	222,000	9,200	231,000
Utah	46,500	(6)	46,500	95,300	(7)	95,300
Vermont	10,700	(6)	10,700	10,700	(7)	10,700
Virginia	100,000	--	100,000	100,000	--	100,000
Washington	61,700	(6)	61,700	62,600	(7)	62,600
West Virginia	13,300	2,750	16,000	13,300	2,750	16,000
Wisconsin	84,800	(6)	84,800	84,800	(7)	84,800
Wyoming	23,600	9,930	33,500	23,600	9,930	33,500

W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes aplite.

[3]Excludes volcanic cinder and scoria; included with "Crushed stone."

[4]Withheld to avoid disclosing company proprietary data; included in "Marketable product, underground."

[5]Withheld to avoid disclosing company proprietary data; included in "Ore treated or sold, underground."

[6]Withheld to avoid disclosing company proprietary data; included in "Marketable product, surface."

[7]Withheld to avoid disclosing company proprietary data; included in "Ore treated or sold, surface."

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TABLE 7
MINING METHODS USED AT SURFACE OPERATIONS IN THE UNITED STATES
BY COMMODITY, IN 2005

(Percentage of total material handled)

Commodity	Preceded by drilling and blasting	Not preceded by drilling and blasting[1]
Metal ore:		
Beryllium	100	--
Copper	98	2
Gold	99	1
Gold-silver	100	--
Lead	100	--
Lead-zinc	100	--
Iron	95	5
Magnesium metal	100	--
Molybdenum	100	--
Silver	100	--
Titanium	--	100
Uranium	--	100
Zinc	100	--
Industrial minerals:		
Abrasives	100	--
Barite	8	92
Boron minerals	100	--
Bromine	2	98
Clays	--	100
Diatomite	21	79
Feldspar[2]	50	50
Garnet	48	52
Greensand marl	--	100
Gypsum	98	2
Iodine	--	100
Iron oxide pigments	--	100
Kyanite	100	--
Lithium minerals	--	100
Magnesite	100	--
Magnesium compounds	--	100
Mica, scrap	18	82
Olivine	46	54
Perlite	28	72
Phosphate rock	5	95
Potash	--	100
Pumice[3]	35	65
Salt	--	100
Sand and gravel:		
Construction	--	100
Industrial	--	100
Stone:		
Crushed	99	1
Dimension	--	100
Talc and pyrophyllite	94	6
Tripoli	61	39
Vermiculite	9	91
Wollastonite	100	--
Zeolites	100	--

-- Zero.

[1]Includes drilling and cutting without blasting, dredging, mechanical excavation and nonfloat washing, and other surface mining methods.

[2]Includes aplite.

[3]Excludes volcanic cinder and scoria; included with "Crushed stone."

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TABLE 8

EXPLORATION ACTIVITY IN THE UNITED STATES IN 2005, BY METHOD, COMMODITY, AND STATE[1]

(Meters)

Commodity or State	Churn and diamond drilling	Rotary and reverse circulation drilling	Percussion drilling, other drilling, and trenching	Grand total
Commodity:				
Gold	298,000	812,000	W	1,110,000
Silver	1,510	--	--	1,510
Other[2]	24,100	64,000	236,000	325,000
Total	323,000	876,000	236,000	1,440,000
Percentage of grand total	23	61	16	100
State:				
Alaska	1,340	12,300	W	13,600
Montana	1,510	--	--	1,510
Nebraska	--	63,400	--	63,400
Nevada	281,000	795,000	W	1,080,000
Undistributed[3]	39,600	5,680	236,000	282,000
Total	323,000	876,000	236,000	1,440,000

W Withheld to avoid disclosing company proprietary data; included with "Other" or "Undistributed." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes boron minerals, diatomite, iron ore, lead, uranium, and commodities indicated by symbol W.

[3]Includes California, Colorado, Idaho, Minnesota, North Carolina, and States indicated by symbol W.

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ABRASIVES, MANUFACTURED

By Donald W. Olson

Domestic survey data and tables were prepared by Nicholas A. Muniz, statistical assistant.

In 2005, estimated United States and Canadian combined production of regular-grade fused aluminum oxide was 10,000 metric tons (t) with a value estimated to be $4.9 million. The U.S. apparent consumption of fused aluminum oxide was an estimated 232,000 t with an estimated value of $64.4 million. U.S. silicon carbide production was an estimated 35,000 t with an estimated value of $21.5 million. The U.S. apparent consumption of silicon carbide was estimated to be more than 220,000 t with an estimated value of $132 million. U.S. production of metallic abrasives was 209,000 t valued at $102 million. U.S. shipments of metallic abrasives sold or used was 226,000 t, with a value of $116 million. The U.S. apparent consumption of metallic abrasives was estimated to be 199,000 t with an estimated value of $92.4 million.

This report includes information on the following abrasives manufactured in the United States: aluminum-zirconium oxide, boron carbide, fused aluminum oxide, metallic shot and grit, and silicon carbide. In some cases, United States production data were combined with Canadian output to avoid disclosing company proprietary data and still provide useful data on the overall Canadian-United States market. Trade data in this report are from the U.S. Census Bureau. All percentages in the report were computed using the unrounded data.

Abrasives play an important role in the fashioning and finishing of many products with a wide range of uses. Abrasives are natural or manufactured substances that are used to abrade, clean, etch, grind, polish, scour, or otherwise remove solid material by rubbing action (as in a grinding wheel) or impact (as in pressure blasting). The most important physical properties for abrasives are character of fracture (cleavage), friability, grain shape and size, hardness (scratch hardness), purity (uniformity), and toughness (rigidity). Additional considerations include availability, bonding characteristics, cost, and thermal stability. Manufactured abrasives are made from metals or minerals by heating or chemically treating them to enhance or give them abrasive properties. No single property is paramount for any use (Wellborn, 1996, p. 31, 43).

Manufactured abrasives generally dominate high-grade abrasives markets as opposed to natural abrasives because they have superior physical properties, more uniform quality, and can be tailored to meet users' needs. Consequently, manufactured abrasives typically are characterized by premium prices relative to natural abrasive minerals. Even though manufactured abrasives are usually more expensive, their durability and efficiency have proven to be more cost effective. They are preferred in many industrial applications, such as metal finishing, cutting, and polishing. In the United States, large volumes of abrasives also are used in cutting and finishing wallboard and timber. The abrasives market is mature, and the use of various manufactured abrasive materials is fairly well defined by application (Kendall, 2001, p. 55).

Fused Aluminum Oxide

Legislation and Government Programs.—As of January 1, 2006, the National Defense Stockpile (NDS) maintained by the U.S. Department of Defense (DOD) contained 6,224 t of fused aluminum oxide abrasive grain valued at about $2.2 million. During 2005, the DOD reported sales of 2,064 t of NDS aluminum oxide abrasive grain for about $871,000. All the NDS crude fused aluminum oxide had been sold during 2000. Under Federal legislation authorizing the disposal of all NDS aluminum oxide, the DOD planned to continue such sales until all the stockpiled aluminum oxide was sold (Janet Rollins, market analyst, Defense National Stockpile Center, oral commun., February 21, 2006).

Production.—Production data for regular and high-purity fused aluminum oxide in this report were obtained by the U.S. Geological Survey (USGS) from producers in Canada and the United States. The data were collected from two companies that operated three plants and represented the entire Canadian and United States fused aluminum oxide industry (table 1). Norton Co. operated a fused aluminum oxide plant in the United States, and Washington Mills Electro Minerals Co. operated fused aluminum oxide plants in Canada and the United States. Data from the two countries were combined to avoid disclosing company proprietary data.

Estimated production of regular-grade fused aluminum oxide in 2005 was 10,000 t with an estimated value of $4.9 million. This was about a 50% decrease in weight and a 25% decrease in value compared with 2004 regular-grade fused aluminum oxide production (table 2). Reporting on the output of high-purity fused aluminum oxide has been discontinued to avoid disclosing company proprietary data.

Consumption.—In all sections of this report, consumption is defined as apparent consumption, which is domestic production plus imports minus exports plus adjustments for Government and industry stock changes. Abrasive-grade fused aluminum oxide has many end uses. Specific applications in 2005 included antislip additives, bonded abrasives (such as abrasive grains that are made to adhere to each other and then are pressed or molded into abrasive tools), buffing/polishing compounds, coated abrasives (such as abrasive grains glued to a backing of paper or cloth), dry or wet blasting media, and tumbling media. Fused aluminum oxide in a micropowder form was used for industrial and electronic applications that require fine surface finishing. Fused aluminum oxide does not face any significant substitution threats at present as it is generally a very cost-effective abrasive. The total U.S. apparent consumption of fused aluminum oxide was an estimated 232,000 t with an estimated value of $64.4 million in 2005.

Prices.—The USGS canvassed fused aluminum oxide producers to determine the total value of their production for the

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year. The survey indicated that the average unit value of regular fused aluminum oxide produced in Canada during 2005 was $144 per metric ton at the point of production; the average value of high-purity fused aluminum oxide output was $656 per ton at the point of production. Prices of abrasive grain produced from these materials and sold to consumers were significantly higher. The average price of NDS fused aluminum oxide grain sold in 2005 was $422 per ton.

Average unit values of fused aluminum oxide traded by the United States in 2005 as reported here are based on U.S. Census Bureau customs value data. The average value for U.S. exports of fused aluminum oxide during the year was about $3,250 per ton. Average unit values of crude fused aluminum oxide imports during the year ranged from $293 per ton (China) to $509 per ton (Canada), and those of fused aluminum oxide grain imports ranged from $468 per ton (South Africa) to $3,120 per ton (United Kingdom).

Foreign Trade.—Compared with the previous year, crude fused aluminum oxide exports in 2005 remained about the same at 13,900 t, and the value of those exports increased by 9% to $45.1 million (table 5). Of the exports shipped to 32 countries, 72% went to Canada, Germany, and Mexico.

During 2005, imports of crude fused aluminum oxide were received from 15 countries and increased by 9% to 198,000 t valued at $62.1 million compared with those of 2004, and imports of ground and refined fused aluminum oxide were received from 22 countries and decreased by 10% to 46,100 t valued at $46.6 million (table 6). Some of the imported crude fused aluminum oxide was refractory-grade material. China, Venezuela, and Canada supplied 85%, 11%, and 4%, respectively, of the crude imports. Compared with 2004, crude imports from China increased by 15%, and from Venezuela, by 37%, while imports from Canada decreased by 61%. Brazil, Germany, Austria, Canada, and Italy provided 23%, 22%, 14%, 10%, and 10%, respectively, of the ground and refined material.

Silicon Carbide

Legislation and Government Programs.—The DOD completed sales of its stockpiled silicon carbide in 1999 (Janet Rollins, market analyst, Defense National Stockpile Center, oral commun., February 21, 2006). The DOD was not expected to replenish the silicon carbide stockpile.

Production.—One company produced abrasive-grade silicon carbide in the United States during 2005 (table 1). This company also produced similar amounts of metallurgical-grade silicon carbide. A second company, in Hopkinsville, KY, produced a small quantity of silicon carbide, primarily intended for use in heat-resistant products rather than abrasives. U.S. silicon carbide production increased slightly during 2005 to an estimated 35,000 t, and the value of production also increased slightly to an estimated $21.5 million (table 2).

Consumption.—Abrasive-grade silicon carbide has many end uses. Specific applications in 2005 included antislip abrasives, blasting abrasives, bonded abrasives, coated abrasives, polishing/buffing compounds, tumbling media, and wiresawing abrasives. The total silicon carbide consumed in the United States was estimated to be about 220,000 t valued at more than $132 million in 2005.

Prices.—Based on information from industry sources and publications, the average value of abrasive-grade silicon carbide at the point of manufacture was estimated to be about $603 per ton in 2005. The average value of total U.S. ground silicon carbide exports in 2005 was approximately $970 per ton.

During 2005, imports from China accounted for 73% of total United States crude silicon carbide imports. This Chinese material had an average value of $520 per ton. The average value of the remaining 27% of U.S. crude silicon carbide imports was $397 per ton. The average value of silicon carbide grain imports was $1,161 per ton; China accounted for 30% of such imports (table 6).

Foreign Trade.—During 2005, the United States exported crude silicon carbide and refined and ground silicon carbide to 30 countries each. The total crude silicon carbide exports for 2005 increased by 78% compared with those of the previous year to 6,610 t valued at $8.69 million (table 5). Compared with 2004, exports of refined or ground silicon carbide decreased by about 12% to 8,940 t valued at $8.67 million. Approximately 86% of the refined and ground material was shipped to Canada.

In 2005, the United States imported crude silicon carbide from 10 countries and ground and refined silicon carbide from 20 countries. Imports of crude silicon carbide decreased by about 5% during the year to 156,000 t valued at $75.8 million (table 6). Imports of silicon carbide in ground or refined form decreased slightly to 45,000 t valued at $52.2 million. China accounted for 73% of the crude silicon carbide imports and 30% of the ground and refined silicon carbide. A large part of the imports from China reportedly included metallurgical-grade material.

Aluminum-Zirconium Oxide

During 2005, fused aluminum-zirconium oxide for abrasive applications, such as resin-bonded grinding wheels, was produced at one plant in the United States and one plant in Canada, both belonging to Norton Co., but production data from the producing plants are withheld to avoid disclosing company proprietary information.

Boron Carbide

Washington Mills was the only commercial producer of boron carbide in the United States during 2005. Boron carbide was used as abrasives for lapping and ultrasonic cutting operations previously possible only with diamond dust; it was also molded to form highly wear-resistant products, such as pressure blasting nozzles, wire-drawing dies, powdered metal and ceramic forming dies, thread guides, and armor. Boron carbide was also used in nuclear applications, such as reactor control rods and neutron absorbing shielding (Washington Mills Electro Minerals Co., 2006§[1]). Domestic production data for boron carbide are withheld to avoid disclosing company proprietary data.

[1]A reference that includes a section mark (§) is found in the Internet Reference Cited section.

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Metallic Abrasives

Production.—Data on U.S. production and shipments of metallic abrasives were based on a survey of domestic producers conducted by the USGS. Survey data were collected from 13 companies operating 15 plants in the United States and accounted for all domestic production (table 3).

Steel shot and grit accounted for almost all the metallic abrasives produced domestically (table 4). U.S. production of steel shot and grit in 2005 increased by 8% compared with that of 2004; the average value was $456 per ton. Seven companies reported production of cut wire shot in 2005, and most of that was cut from carbon steel wire and stainless steel wire. Other products reported included shot cut from aluminum, copper, and zinc wire. One company reported production of steel nuggets, a wrought carbon steel blast medium with properties similar to steel shot.

Consumption.—Metal abrasives are used primarily as loose particles propelled at high velocities for blast cleaning or to improve the properties of metal surfaces; approximately 75% of the abrasives is employed in cleaning operations. Principal consumers include foundries, machine tool industries, metalworking plants (particularly those supporting the automotive and aircraft industries), and steel manufacturers.

During 2005, total sales of all steel shot and grit by U.S. producers increased by 12% compared with shipments in 2004 to about 226,000 t with an average value of $512 per ton sold or used.

Prices.—The USGS compiles survey data on the value of production and shipments, but it does not collect price data. The values of production and shipments reported by metallic abrasive producers in 2005 are listed in table 4. Average values of steel shot and grit ranged from $0.38 to $1.11 per kilogram. Average values of cut wire shot ranged from $4.42 to $6.27 per kilogram for aluminum wire shot and from $2.88 to $6.23 per kilogram for stainless steel wire shot. Average unit values for metallic abrasives traded by the United States during 2005 were as follows: exports, $0.80 per kilogram, and imports, $0.76 per kilogram.

Foreign Trade.—During 2005, the United States exported metallic abrasives to 39 countries and imported metallic abrasives from 13 countries. U.S. exports of metallic abrasives increased slightly during the year to 26,900 t valued at $21.6 million (table 5). Canada and Mexico received 85% of the U.S. exports of metallic abrasives in 2005. U.S. imports increased by 4% in 2005 to 16,500 t valued at $12.5 million (table 6). About 63% of the imports came from Canada; most of the remaining imports, in descending order, were shipped from Germany, China, South Africa, and Romania.

Outlook

Abrasives markets closely follow economic and technological trends and are greatly influenced by activity in the manufacturing sector in the United States. This is particularly true of manufacturing activities in the aerospace, automotive, furniture, housing, and steel industries. Even though abrasives markets are linked to these end-use manufacturing sectors, growth in these sectors may not necessarily lead to an increase in abrasives consumption. Improved technology in these manufacturing sectors is resulting in surface quality that requires less grinding and finishing operations that use abrasives (O'Driscoll, 2003). Less expensive imports and higher domestic costs will continue to challenge U.S. producers of fused aluminum oxide and silicon carbide to maintain market share. Competition from developing nations, especially China, will probably lead to further decreases in domestic output. China has become a dominant force in both fused aluminum oxide and silicon carbide in recent years. This has changed the makeup of the manufactured abrasives market. Lower priced Chinese exports have displaced and will continue to displace manufactured abrasive produced in Europe and North America (Gasser, 2002). The traditional suppliers among the Western industrialized nations are expected to continue consolidating and contracting.

Emerging suppliers of fused aluminum oxide and silicon carbide in China, Eastern Europe, India, the Republic of Korea, and South America will continue to increase their prominence in world markets. Further success for these suppliers, particularly in such major markets as Japan, the United States, and Western Europe, will depend on their ability to provide higher grades of material and levels of supply reliability while maintaining lower prices. Energy costs, furnace size, quality-control systems, and the availability of essential mineral inputs will be the dominant factors influencing the competitive stance of these suppliers (O'Driscoll, 1997; Zhilun, 1997; Lunghofer and Wolfe, 1998).

The housing construction sector in North America will continue to have a significant indirect influence on demand for manufactured abrasives because of the large volumes of manufactured abrasives used in cutting and finishing wallboard and timber. The aerospace and automotive manufacturing sectors also will continue to be significant indirect influences on demand for manufactured abrasives used by metalworking operations supporting those sectors.

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TABLE 1
CRUDE ARTIFICIAL ABRASIVES MANUFACTURERS IN 2005

Company	Plant location	Product
Exolon Co., The	Hennepin, IL	Silicon carbide.
Norton Co.	Huntsville, AL	Fused aluminum oxide (high-purity) and aluminum-zirconium oxide.
Do.	Chippewa, Ontario, Canada	Aluminum-zirconium oxide.
Washington Mills Electro Minerals Corp.	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular).
Do.	Niagara Falls, NY	Fused aluminum oxide (high-purity) and boron carbide.

TABLE 2
ESTIMATED PRODUCTION OF CRUDE SILICON CARBIDE AND FUSED ALUMINUM OXIDE IN THE UNITED STATES AND CANADA[1, 2]

	2004		2005	
Product	Quantity[3, 4] (metric tons)	Value[3] (thousands)	Quantity[3, 4] (metric tons)	Value[3] (thousands)
Aluminum oxide, regular, abrasives[5]	20,000	$6,500	10,000	$4,900
Silicon carbide[6]	35,000	21,500	35,000	21,500

[1]Data are rounded to no more than three significant digits.
[2]Yearend stock data are withheld to avoid disclosing company proprietary data.
[3]Owing to rounding, data do not match total quarterly Mineral Industry Surveys estimated data.
[4]Quantities are rounded to the nearest 5,000 tons to avoid disclosing company proprietary data.
[5]Regular grade normally accounts for about 48% of total output, and high-purity material accounts for the remainder.
[6]Approximately one-half of the quantity and value consists of material for metallurgical and other nonabrasive applications.

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TABLE 3
U.S. PRODUCERS OF METALLIC ABRASIVES IN 2005

Company	Plant location	Product (shot and/or grit)
Abrasive Materials Inc.	Hillsdale, MI	Cut wire.
Chesapeake Specialty Products, Inc.	Baltimore, MD	Steel.
Ervin Industries, Inc.	Adrian, MI	Do.
Do.	Butler, PA	Do.
Do.	do.	Do.
Frohn North America, Inc.	Austell, GA	Cut wire.
Marwas Steel Co.	Scottdale, PA	Do.
Metaltec Steel Abrasives Co.	Canton, MI	Steel.
National Metal Abrasive Inc.	Wadsworth, OH	Do.
Peerless Metal Powders & Abrasive Co., Inc.	Detroit, MI	Steel and steel nuggets.
Pellets, Inc.	Tonawanda, NY	Cut wire.
Platt Brothers, Inc., The	Waterbury, CT	Do.
Premier Shot Co.	Cleveland, OH	Do.
U.S. Filter Abrasive Materials, Inc.	Hillsdale, MI	Do.
Wheelabrator Abrasives, Inc.	Bedford, VA	Steel.

TABLE 4
PRODUCTION AND SHIPMENTS FOR METALLIC ABRASIVES IN THE UNITED STATES, BY PRODUCT[1]

	Production		Shipments[2]	
Product	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
2004:				
Steel shot and grit	193,000	$87,800	200,000	$92,700
Cut wire shot and other[e]	1,260	4,250	1,310	4,750
Total	194,000	92,000	201,000	97,400
2005:				
Steel shot and grit	207,000	94,400	224,000	108,000
Cut wire shot and other[e]	2,120	7,170	2,150	7,580
Total	209,000	102,000	226,000	116,000

[e]Estimated.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes reported exports.

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TABLE 5
U.S. EXPORTS OF ALUMINUM OXIDE, SILICON CARBIDE, AND METALLIC ABRASIVES, BY COUNTRY AND TYPE[1]

	2004		2005	
Country	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Aluminum oxide, crude:				
Belgium	425	$722	452	$4,440
Brazil	587	3,100	497	2,590
Canada	3,280	4,010	3,290	3,400
China	104	1,220	78	1,220
Germany	4,610	15,100	4,560	15,000
India	163	610	279	925
Japan	1,270	6,920	1,570	9,210
Korea, Republic of	921	4,320	566	2,670
Mexico	2,200	2,850	2,150	2,770
Other	383 r	2,380 r	452	2,910
Total	13,900 r	41,200 r	13,900	45,100
Silicon carbide:				
Crude:				
Finland	34	99	208	627
Germany	33	89	105	387
Japan	1,070	2,440	134	1,400
Mexico	174	455	458	877
Norway	2,290	1,480	5,470	4,320
Other	109 r	946 r	235	1,090
Total	3,720 r	5,510	6,610	8,690
Ground and refined:				
Canada	8,830	5,690	7,640	5,950
China	17	52	34	184
Costa Rica	28	69	24	69
Finland	119	348	--	--
France	65	214	51	143
Germany	127	379	75	91
Korea, Republic of	29	138	29	170
Mexico	411	508	278	492
Norway	109	199	331	206
Russia	97	298	--	--
Spain	62	141	44	108
United Kingdom	195	319	139	187
Other	82 r	693	287	1,080
Total	10,200 r	9,050	8,940	8,670
Metallic abrasives:				
Australia	125	83	47	28
Canada	11,500	7,070	11,200	7,290
China	38	305	141	790
France	150	171	200	187
Italy	136	51	138	74
Japan	400	234	2,080	1,240
Mexico	13,500	11,300	11,600	9,880
Taiwan	154	176	466	315
Vietnam	151	53	--	--
Other	391 r	1,180 r	1,030	1,750
Total	26,500 r	20,600 r	26,900	21,600

rRevised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Customs value.

Source: U.S. Census Bureau.

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TABLE 6
U.S. IMPORTS OF ALUMINUM OXIDE, SILICON CARBIDE, AND METALLIC ABRASIVES, BY COUNTRY AND TYPE[1]

	2004		2005	
Country	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Aluminum oxide:				
Crude:				
Canada	20,100	$8,140	7,880	$4,010
China	145,000 r	35,600 r	167,000	49,000
Venezuela	15,100	6,280	20,700	8,140
Other	1,290	581 r	1,980	957
Total	181,000 r	50,600 r	198,000	62,100
Ground and refined:				
Austria	6,470	8,660	6,370	9,150
Brazil	8,980	5,610	10,500	8,080
Canada	5,010	3,590	4,690	3,130
China	2,810	1,090	1,540	818
France	2,150	3,360	714	946
Germany	10,400	13,100	10,300	13,200
Hungary	3,340	2,510	3,420	2,660
Italy	4,580	3,220	4,450	3,570
South Africa	960	448	1,820	850
United Kingdom	976	2,890	590	1,840
Venezuela	3,990	1,430	--	--
Other	1,580 r	1,860 r	1,760	2,290
Total	51,200	47,800	46,100	46,600
Silicon carbide:				
Crude:				
Brazil	12,000	5,520	1,980	1,030
China	92,800	41,900	113,000	58,800
Netherlands	17,100	5,220	5,830	1,140
Romania	13,500	4,550	16,100	4,350
Russia	6,030	2,430	2,060	1,040
Venezuela	21,100	7,880	14,300	6,030
Other	690	1,810	2,360	3,360
Total	163,000	69,300	156,000	75,800
Ground and refined:				
Brazil	11,600	7,870	10,700	7,600
China	16,100	11,800	13,400	11,400
Japan	1,320	6,360	1,380	6,980
Norway	3,270	10,500	2,270	8,540
Philippines	2,190	1,490	--	--
Russia	3,940	1,980	9,990	5,810
Venezuela	3,490	2,070	3,380	3,760
Vietnam	1,170	793	1,960	1,430
Other	2,270 r	7,070 r	2,000	6,710
Total	45,300	49,900	45,000	52,200
Metallic abrasives:				
Canada	11,300	5,660	10,300	5,450
China	59	56	1,480	1,270
Germany	1,230	1,490	2,270	3,550
Other	3,310 r	2,310 r	2,410	2,250
Total	15,900 r	9,520	16,500	12,500

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Customs value.

Source: U.S. Census Bureau.

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ALUMINUM

By Patricia A. Plunkert

Domestic survey data and tables were prepared by Benjamin S. Goff, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

In 2005, 6 domestic companies operated 14 primary aluminum smelters in 12 States and produced 2.48 million metric tons (Mt) of metal. Smelters east of the Mississippi River accounted for about 70% of the production. The value of U.S. production was estimated to be $4.98 billion. Five smelters were temporarily idled during the year. At yearend, about 1.2 million metric tons per year (Mt/yr) of domestic primary aluminum smelting capacity, including idled potlines at operating smelters, equivalent to about 32% of total capacity, was closed.

Aluminum recovered from purchased scrap decreased to 2.99 Mt. Of this recovered metal, about 64% came from new (manufacturing) scrap, and 36% came from old (discarded aluminum products) scrap. Aluminum used beverage cans (UBCs) accounted for about 60% of the reported old scrap consumption in 2005. According to the Aluminum Association Inc. (2006a), the recycling rate for aluminum UBCs was 52%.

The transportation and the container and packaging industries remained the leading markets for aluminum products in Canada and the United States in 2005. The transportation industry accounted for 37% of domestic metal shipments; containers and packaging, 22%; building and construction, 16%; consumer durables, 7%; electrical, 7%; machinery and equipment, 7%; and other uses, 4%.

U.S. imports for consumption of aluminum materials increased by 13% in 2005 compared with those of 2004. Canada remained the leading shipper of aluminum materials to the United States, followed by Russia. Total exports of aluminum materials from the United States in 2005 increased by 30% compared with those of 2004.

The monthly average U.S. market price of primary aluminum ingot increased dramatically during the latter half of 2005, exceeding $1.00 per pound for the first time since January 1989. The 2005 annual average price increased to 91.06 cents per pound from 84.01 cents per pound in 2004.

At the end of 2005, total world inventories of aluminum, as reported by the International Aluminium Institute (IAI) (2006), increased slightly compared with those of 2004. Combined inventories of aluminum metal and alloys held by the London Metal Exchange Ltd. (LME), however, decreased.

Primary aluminum was produced in 42 countries in 2005. China, Russia, Canada, and the United States, in decreasing order of metal produced, accounted for more than one-half of total world production. World primary metal production increased by about 7% compared with that of 2004. The increase in production in China was responsible for most of this increase in world production.

Production

Primary.—Domestic primary aluminum production, which totaled a reported 2,480,999 metric tons (t), decreased by 1% compared with that of 2004. Production data were obtained from the six operating domestic producers, all of whom responded to the U.S. Geological Survey (USGS) request for production data.

In December, Alcoa Inc. closed its 195,000-metric-ton-per-year (t/yr) Eastalco primary aluminum smelter in Frederick, MD. The facility was unable to secure a new, long-term, competitive power supply to replace the power arrangement with Allegheny Power that expired on December 31 (Alcoa Inc., 2005j).

Ormet Corp. temporarily closed the last two of six potlines at its 265,000-t/yr smelter in Hannibal, OH. The company reportedly based its decision on the continuing work stoppage by union employees at the facility and delays in raw material deliveries caused by the extended closing of the Belleville Locks and Dam on the Ohio River (Ormet Corp., 2005).

Century Aluminum Co. signed a memorandum of understanding (MOU) with Big Rivers Electric Corp. and Kenergy Corp. that would restructure and extend through 2023 the electricity service contract for its Hawesville, KY, primary aluminum smelter (Century Aluminum Co., 2005a). Alcan Inc. also signed an MOU with Big Rivers and Kenergy to restructure and extend the existing electricity service contract for its Sebree, KY, smelter through 2023. Both contracts were subject to approval by State and local regulators (Alcan Inc., 2005i).

Century also signed an agreement with Appalachian Power Company for electrical service to its Ravenswood, WV, smelter effective January 1, 2005. The agreement, which replaced the expired contract with Ohio Power Company, had an initial term of 2 years but would continue until Century gave a 12-month notice of cancellation. Both Appalachian and Ohio Power were subsidiaries of American Electric Power Company (Century Aluminum Co., 2005d).

Alcoa and TXU Energy Co. signed a letter of intent covering the development, construction, ownership, operation, and maintenance of a fifth power generating station at Alcoa's Rockdale, TX, smelter. The proposed new generating station would replace three of the four existing stations and guarantee that the smelter's power requirements would be met through 2038 (Alcoa Inc., 2005o).

Alcoa also announced investments to secure the long-term power needs of its Warrick, IN, smelter. The company planned to invest $45 million to purchase equipment and the rights to mine coal from Vigo Coal Co. The investment also called for the addition of a coal preparation facility and material handing infrastructure to transport the coal to Alcoa's onsite powerplant. The mine would produce about 1 Mt/yr of coal, approximately 45% of the powerplant's annual fuel requirements (Alcoa Inc., 2005l). Alcoa also planned to invest $330 million at its Newburgh, IN, powerplant to increase environmental performance and power efficiency and to lower costs. The plans

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included the installation of scrubbers, boiler modifications to provide greater fuel flexibility, and the installation of new and improved coal handling facilities (Alcoa Inc., 2005f).

Alcan and workers represented by United Steelworkers (USW) ratified a new 5-year labor agreement at the Ravenswood rolling mill. The new contract, effective June 1, will expire on May 31, 2010. The mill produced aluminum plate, coil, and sheet products for the aerospace, aeronautical, and transportation industries (Alcan Inc., 2005h).

Kaiser Aluminum Corp. and USW ratified 5-year labor agreements covering workers at multiple Kaiser plants. The agreements, which will expire in 2010, covered workers in Newark, OH; Tulsa, OK; Richmond, VA; and Spokane, WA. The agreements provided similar terms at each plant, including a ratification bonus, a typical industry-level wage increase, and the opportunity to share in plant profitability (Kaiser Aluminum Corp., 2005b).

Kaiser announced a $75 million expansion at its Trentwood, WA, rolling mill. The expansion included the addition of a state-of-the-art thick-plate stretcher, horizontal heat-treat furnaces, an ultrasonic inspection system, and other ancillary equipment that would enable Kaiser to supply heavy-gauge, heat-treat stretched plate to the aerospace and general engineering markets. The project was expected to be completed in 2008 (Kaiser Aluminum Corp., 2005c).

JW Aluminum Co. completed the initial phase of a major expansion program at its Russellville, AR, rolling mill. Capacity at the facility increased by 27,000 t/yr (60 million pounds per year). The expansion was in response to increased finstock (coiled aluminum sheet or foil used in manufacture of fins for heat exchanger applications) demand by the air conditioning industry. In addition to finstock, the mill produced light gauge converter foil for the flexible packaging industry, heavier gauge sheet for the building and construction markets, and other foil and sheet products (JW Aluminum Co., 2005).

Alcan announced a $27 million expansion at its Ravenswood rolling mill. Upon completion, scheduled for 2006, the expansion would increase the plant's production of aluminum plate, coil, and sheet products for the aerospace, aeronautical, and transportation industries. In October, Alcan signed a multiyear agreement with The Boeing Company to supply the aircraft manufacturer with a variety of high-performance aluminum products (Alcan Inc., 2005g).

Alcan announced the closure of its Vernon, CA, aluminum cast plate facility effective January 21, 2006. The plant produced aluminum cast plates for the mold- and tool-making industries (Alcan Inc., 2005k).

In early 2005, Honeywell International Inc. acquired Indalex Aluminum Solutions Group as part of its purchase of Novar Plc. In September, Sun Capital Partners Inc. agreed to purchase Indalex from Honeywell for $425 million. Indalex is North America's leading independent supplier of extruded aluminum components and services with 2 casthouses and 16 extrusion facilities in the United States and Canada (Indalex Aluminum Solutions Group, 2005, 2006).

Ohio Valley Aluminum Co. acquired the assets of Boonville Casting, an aluminum billet casting company in Boonville, IN. The transaction added 41,000 t/yr (90 million pounds per year) to Ohio Valley's aluminum extrusion billet casting capacity (Ohio Valley Aluminum Co., 2005§[1]).

Secondary.—Metal recovered from new and old scrap decreased to 2.99 Mt in 2005, according to data derived by the USGS from its "Aluminum Scrap" survey (table 3). Of the 59 companies and/or plants to which monthly or annual survey requests were sent, 36 responded; they represented 82% of the total scrap consumed reported in table 4.

According to figures released by the Aluminum Association, the Can Manufacturers Institute, and the Institute of Scrap Recycling Industries Inc., 51.4 billion aluminum UBCs were recycled in the United States in 2005, for an aluminum beverage can recycling rate of 52%, a 0.8% increase from the 2004 rate (Aluminum Association Inc., 2006a).

Aleris International Inc., the company formed in 2004 from the merger of IMCO Recycling Inc. and Commonwealth Industries Inc., announced several acquisitions in 2005. Aleris purchased ALSCO Holdings Inc. (the parent of company of ALSCO Metals Corp.) (Aleris International Inc., 2005b). Headquartered in Raleigh, NC, ALSCO was a leading supplier of aluminum building products. ALSCO operated a rolling mill in Bellwood, VA, and coating and fabrication facilities in Roxboro, NC, Ashville, OH, and Beloit, WI (Aleris International Inc., 2005f). Following the purchase of ALSCO, Aleris evaluated its production facilities for potential redundancy and decided to permanently close and dismantle its Carson, CA, rolling mill and coating facility. The Carson mill supplied semifabricated aluminum coil and painted coil for building and construction, consumer durables, and electrical applications (Aleris International Inc., 2005e).

In addition to ALSCO, Aleris purchased certain assets of Ormet (Aleris International Inc., 2005d). Aleris planned to transfer selected equipment from Ormet's Hannibal rolling mill to its other mills, which was expected to increase Aleris' production capacity by about 57,000 t/yr (125 million pounds per year). Ormet's Bens Run, WV, recycling facility was to become part of Aleris's Aluminum Recycling segment. Aleris expanded its product line with the purchase of Specialty Blanks Inc, which produced aluminum fabricated products automotive wheels, cookware, and lighting (Aleris International Inc., 2005g).

In December, Aleris also completed the purchase of Alumitech Inc., an aluminum recycling operation headquartered in Cleveland, OH, from Zemex Corp. (Aleris International Inc., 2005c).

Wabash Alloys LLC announced plans to close its secondary aluminum smelter in Cleveland and move most of its production to the company's Wabash, IN, plant. Wabash is a leading producer of specification aluminum alloy from aluminum scrap with four smelters in the United States (excluding the Cleveland plant), two smelters in Canada, and one smelter in Mexico. North American production capacity was estimated to be about 590,000 t/yr (1.3 billion pounds per year) of metal (Schaffer, 2005b).

Arkansas Aluminum Alloys Inc. fired up a third furnace at its Hot Springs, AR, secondary aluminum plant that increased capacity to about 59,000 t/yr (130 million pounds per year). The facility produces specification aluminum ingot for diecasters and foundries in the United States (Platts Metals Week, 2005a).

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[1]References that include a section mark (§) are found in the Internet References Cited section.

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Jupiter Aluminum Corp. announced plans to expand capacity at its Hammond, IN, rolling mill to 159,000 t/yr (350 million pounds per year) from 109,000 t/yr (240 million pounds per year). The mill produces 3000 series alloys from aluminum scrap for residential siding and gutters as well as cookware and lighting components. A specialty of the mill is license plate coil used by the California, Illinois, and Indiana State governments (Schaffer, 2005a).

Kentucky Smelting Technology Inc. [a joint venture between Toyota Tsusho America Inc. (New York, NY) and Toyota Tsusho America's parent company Toyota Tsusho Corp. (Tokyo, Japan)] announced plans to build an aluminum smelting facility in Paris, KY. The new facility will produce molten aluminum alloys for Central Manufacturing Corp./Central Light Alloy (CMC/CLA), a manufacturer of aluminum wheels. CMC/CLA expected to double its production of aluminum wheels to 1.5 million wheels by late 2005 (Kentucky Cabinet for Economic Development, 2005§).

Industry Merger.—Falconbridge Limited and Noranda Inc. merged to form a new company that would continue under the name Falconbridge Limited. Falconbridge was a producer of nickel, copper, cobalt, and platinum-group metals as well as being one of the world's leading recyclers and processors of metal-bearing materials. Noranda was a copper and nickel company with investments in fully integrated aluminum and zinc assets. Noranda's primary aluminum smelter in New Madrid, MO, rolling mills, alumina refinery in Gramercy, LA, and bauxite operations in Jamaica were to continue to operate as a wholly owned subsidiary, Noranda Aluminum Inc. (Falconbridge Limited, 2005).

Consumption

According to the combined United States and Canada end-use shipment data for 2005 reported by the Aluminum Association, shipments of aluminum products to the transportation industry totaled 3.94 Mt. Shipments to the container and packaging industry, which was the second ranked end-use market, were 2.32 Mt. Total shipments, excluding exports, of aluminum products in 2005 increased slightly compared with those of 2004 (table 6).

The revival of the global aerospace industry led to the signing of several multiyear supply agreements between aircraft manufacturers and aluminum companies. Alcoa announced the signing of a multiyear contract (2005-09) with Chinese aircraft manufacturer Shanghai Aircraft Manufacturing Factory to provide aluminum extrusions for the horizontal stabilizer tail section assembly of the Boeing 737. In December 2004, Alcoa had signed a similar supply agreement for 2005 to 2007 with Xian Aircraft of China (Alcoa Inc., 2005c). Alcoa also signed a long-term agreement, which runs through December 2011, to supply Airbus S.A.S. with high-performance sheet and plate products for its new A380F cargo and A350 wide body passenger planes (Alcoa Inc., 2005m). To help meet the increase in demand for aerospace products, Alcoa announced plans to increase its global aerospace heat-treated sheet and plate production capacity by 50%. Expansions were scheduled for the Davenport, IA, mill and mills in Italy, Russia, and the United Kingdom (Alcoa Inc., 2005k).

Kaiser signed a long-term contract with Boeing to supply heavy-gauge aluminum plate for use in Boeing's commercial aircraft products (Kaiser Aluminum Corp., 2005a). Kaiser also signed a new agreement to supply Airbus with heat-treated aluminum sheet and plate from 2005 through 2011 (Kaiser Aluminum Corp., 2005d).

Alcan signed a multiyear agreement to supply Boeing with a variety of high-performance aluminum products primarily for Boeing's 737 and 777 commercial aircrafts. Alcan's Ravenswood rolling mill would be the major source of these materials (Alcan Inc., 2005a). Corus Group plc signed a 5-year agreement (2007-11) with Airbus to supply 20,000 t/yr of aluminum plate and sheet for commercial and military aircraft and helicopters (Corus Group plc, 2005).

In the automotive sector, Alcoa signed a letter of intent with Fujikura Ltd. (Toyota, Japan) in which Alcoa would obtain complete ownership of Alcoa Fujikura Limited's (AFL) automotive business based in Detroit, MI, and Fujikura would obtain full ownership of AFL's telecommunications businesses based in Nashville, TN. Alcoa and Fujikura held 51% and 49%, respectively, of the two AFL business units prior to the planned change in ownership. According to the companies, the realignment would allow each of the companies to focus on their respective core capabilities (Alcoa Inc., 2005d). Alcoa announced the closure of its Hawesville, KY, automotive casting facility owing to excess capacity in its automotive castings manufacturing system. Alcoa expected to continue operating its automotive casting facilities in Farsund, Norway, and Fruitport, MI (Alcoa, 2005i). Alcoa opened a new manufacturing plant in Salisbury, NC, to provide wheel and tire assemblies for Freightliner LLC facilities in North Carolina and South Carolina. Freightliner is the leading heavy-duty truck manufacturer in North America and a leading manufacturer of medium-duty and specialized commercial vehicles (Alcoa Inc., 2005g).

Bodine Aluminum Inc. (a subsidiary of Toyota Motor Manufacturing North America Inc.) began producing cast aluminum engine blocks at its new plant in Jackson, TN. Initial capacity of the plant was 1 million engine blocks per year consuming about 22,700 t/yr (50 million pounds per year) of aluminum. The blocks would be sent to Toyota's engine plant in Georgetown, KY, and then installed in the Camry and Avalon sedans also manufactured in Kentucky (Toyota Motor Corp., 2005).

In order to meet the growing demand for specialty beverage cans, Ball Corporation converted a 12-ounce beverage can line in its Golden, CO, plant to 24-ounce specialty cans. The company subsequently announced plans to convert a can manufacturing line at its plant in Monticello, IN, to 16-ounce cans from 12-ounce cans. Ball operated 19 metal beverage can plants in North America, 12 can plants in Europe, 7 owned and jointly owned packaging plants in China, and 2 joint-venture beverage can plants in Brazil (Ball Corporation, 2005).

Stocks

According to data reported by the Aluminum Association, the combined United States and Canadian producers inventories of aluminum ingot, mill products, and scrap decreased to 1.43 Mt at yearend 2005 from 1.47 Mt in 2004 (Aluminum

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Association Inc., 2006b). The LME, however, reported that primary aluminum metal ingot stocks at its U.S. warehouses increased to 80,100 t at yearend 2005 from 11,900 t at yearend 2004. At yearend 2005, U.S. LME warehouses also held about 129,000 t of North American Special Aluminium Alloy Contract (NASAAC) metal ingot, an increase from the 104,000 t held at yearend 2004 (London Metal Exchange Ltd., 2005).

Prices

The monthly average U.S. market price of primary aluminum metal, as reported by Platts Metals Week, rose dramatically during the latter half of 2005. The monthly average price began the year at 89.75 cents per pound, rose to 96.85 cents per pound by March, and then decreased to 83.35 cents per pound in June, the low average price for the year. In July, the monthly average price began to trend upward and in December reached an average of $1.061 per pound, the first time the monthly average U.S. market price exceeded $1.00 per pound since January 1989. The annual average price in 2005 increased to 91.06 cents per pound, up significantly from 84.01 cents per pound in 2004.

The LME average monthly cash price for high-grade primary aluminum ingot and the average monthly spot settlement price for primary aluminum ingot on the COMEX division of the New York Commodity Exchange, Inc. followed the same general trend as the U.S. market price. The 2005 average annual LME cash price increased to 86.1 cents per pound from 77.8 cents per pound in 2004. The COMEX monthly average spot settlement price increased from 88.4 cents per pound in January to $1.032 per pound in December and averaged 89.3 cents per pound for the year.

Purchase prices for aluminum scrap, as quoted by American Metal Market, also fluctuated during the first half of the year and closed at higher levels than those at the beginning of the year. The 2005 yearend price ranges for selected types of aluminum scrap were as follows: mixed low-copper-content aluminum clips, 67.0 to 68.0 cents per pound; old sheet and cast aluminum, 63.0 to 64.0 cents per pound; and clean, dry aluminum turnings, 62.0 to 63.0 cents per pound.

Aluminum producers' buying price range for processed and delivered UBCs, as quoted by American Metal Market, also closed higher at yearend. The price range began the year at 64.0 to 65.0 cents per pound and closed the year at 74.0 to 76.0 cents per pound. The annual average American Metal Market price for aluminum UBCs increased to 65.4 cents per pound in 2005 from 61.0 cents per pound in 2004.

The yearend indicator prices for selected secondary aluminum ingots, as published in American Metal Market, also increased compared with those at the beginning of the year. The closing prices for 2005 were as follows: alloy A380 (3% zinc content), 96.4 cents per pound; alloy B380 (1% zinc content), 99.2 cents per pound; alloy A360 (0.6% copper content), $1.007 per pound; alloy A413 (0.6% copper content), $1.005 per pound; and alloy 319, $1.010 per pound. Platts Metals Week published an annual average U.S. price of 82.7 cents per pound for A380 alloy (3% zinc content). The average annual LME cash price for a similar A380 alloy was 74.7 cents per pound and the annual average LME NASAAC cash price was 75.4 cents per pound.

Trade

Total exports of aluminum materials from the United States in 2005 were 30% higher than those of 2004 (table 8). About 80% of total U.S. exports in 2005 was shipped to Canada, China, and Mexico. More than 90% of the shipments to China was in the form of aluminum scrap.

Imports for consumption also increased compared with those of the previous year (table 10). Canada remained the major source country accounting for more than one-half of the total imports in 2005, and Russia continued to be the second ranked supplier (table 11).

World Industry Structure

World production of primary aluminum metal increased by 7% in 2005 compared with that of 2004 (table 12). China, Russia, Canada, and the United States, in decreasing order of metal produced, accounted for more than one-half of total world production.

Unwrought aluminum inventories held by members of the IAI increased slightly to 1.80 Mt at yearend 2005 from 1.79 Mt at yearend 2004. Unwrought aluminum is defined by the IAI as aluminum in its basic form made from primary metal or from scrap that is unworked in the metallurgical sense. Total IAI aluminum inventories increased to 3.19 Mt at yearend 2005 from 3.18 Mt at yearend 2004. Total aluminum includes unwrought aluminum plus unprocessed scrap, metal in process, and finished semifabricated (mill) products (International Aluminium Institute, 2006).

Yearend 2005 inventories of primary aluminum metal held by the LME decreased to 644,000 t from 693,000 t at yearend 2004. Aluminum alloy inventories, however, increased to 52,900 t at yearend 2005 from 40,400 t at yearend 2004, and NASAAC ingot inventories increased to 129,000 t at yearend 2005 from 104,000 t at yearend 2004 (London Metal Exchange Ltd., 2005).

World Review

Argentina.—Aluar Aluminio Argentino S.A.I.C. (Aluar) announced the start of an expansion project at its primary aluminum smelter in Puerto Madryn that would increase capacity at the 275,000-t/yr smelter by 122,500 t/yr. The project included construction of a new 90,200-t/yr potline, increasing total capacity at the three existing potlines by 32,300 t/yr, expansion of the anode facility, and construction of a new billet casting station. Completion of the project was scheduled for mid-2007 (Aluar Aluminio Argentino S.A.I.C., 2005§).

Armenia.—RUSAL announced the restart of production at its ARMENAL foil plant in Yerevan upon completion of the first stage of its 18-month modernization program begun in November 2004. In 2007, when the technical upgrades are expected to be completed, the plant will have a 25,000-t/yr capacity including 18,000 t/yr of thin foil (6 to 8 micrometers thick) and 7,000 t/yr of kitchen foil (RUSAL, 2005c).

Bahrain.—Aluminium Bahrain B.S.C. (Alba) commissioned the world's longest aluminum reduction line, which was more than 1 kilometer in length. In addition to the 336 pots in Line 5,

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the $1.7 billion project included a powerplant, a carbon plant, and casthouse improvements. The new 307,000-t/yr potline, which utilized an improved version of AP30 technology, increased the smelter's capacity to 830,000 t/yr, making it one of the world's largest capacity smelters (Aluminium Bahrain B.S.C., 2005).

Brazil.—As part of a $1.6 billion investment in its Brazilian operatons, Alcoa announced plans to modernize its 93,000-t/yr Pocos de Caldas aluminum smelter. The installation of dry scrubbers was expected to lower emissions and costs as well as improve the operating efficiency of the smelter (Alcoa Inc., 2005b).

Companhia Brasileira de Alumínio (CBA) announced a series of investments in its aluminum and energy operations. In addition to expansions at its bauxite mining and refining operations, CBA announced the completion of an expansion at its Alumínio (Sorocoba) smelter in Sao Paulo to 400,000 t/yr and the potential of a further expansion to about 470,000 t/yr in 2007. CBA also announced investments in three additional powerplants with the goal of becoming self-sufficient in its energy requirements (Votorantim Group, 2005§).

Aleris acquired Tomra Latasa Recicigem, a recycling operation in Sao Paulo, from Tomra Systems ASA of Norway. Aleris expected the purchase to provide it with greater access to aluminum scrap and to complement the company's existing operations in Brazil (Aleris International Inc., 2005a).

In 2004, Brazil recycled a record 95.7% of all aluminum beverage cans sold during the year. Brazil collected and recycled more than 9 billion aluminum cans, the equivalent of more than 121,000 t of aluminum, making Brazil the world leader in aluminum can recycling rates for the fourth consecutive year among countries that do not have mandatory recycling laws (Associação Brasiliera do Alumínio, 2005§).

Alcoa's Brazilian affiliate, Alcoa Aluminio S.A., and Tetra Pak, Klabin, and TSL Ambiental opened the world's first aseptic carton packaging recycling facility located in Piracicaba. The plant uses plasma technology, which enables the total separation of the aluminum, paper, and plastic components of the cartons. Other processes separated the paper but kept the plastic and aluminum together. The new facility has the capacity to process 8,000 t/yr of plastic and aluminum, which corresponds to recycling approximately 32,000 t/yr of aseptic packaging (Alcoa Inc., 2005h).

Cameroon.—Alcan and the Government of Cameroon have signed a letter of intent for the potential upgrade and expansion of their joint-venture Alucam smelter and the construction of a new hydroelectric power station at a total estimated cost of $900 million. Capacity at the 90,000-t/yr smelter would increase to 260,000 t/yr through upgrades (20,000 t/yr) to the existing potline and the construction of a second 150,000-t/yr potline. Project feasibility would require the construction of the Lom Pangar dam by the Government. In addition to fulfilling the project's electricity requirements, the Lom Pangar dam would contribute to increasing the overall availability of electricity to Cameroon. A decision on the project was expected by the end of 2006 (Alcan Inc., 2005b).

Canada.—The expansion of the Aluminerie Alouette Inc. aluminum smelter at Sept Iles was completed in June, on budget and 3 months ahead of schedule. Begun in May 2003, the project increased capacity to 550,000 t/yr from 245,000 t/yr. Aluminerie Alouette is a consortium made up of five shareholders—Alcan (40%), Austria Metall AG (20%), Norsk Hydro ASA (20%), Société Générale de Financement du Québec (SGF) (13.33%), and Marubeni Corp. (6.67%) (Aluminerie Alouette Inc., 2005).

Alcan has invested $4.7 million to increase its share of extrusion billet capacity at the Aluminerie de Bécancour Inc. (ABI) smelter of which it holds a 25.05% ownership. Alcoa holds the remainder of the plant. The addition of a continuous homogenization furnace and ancillary casting equipment would increase billet production capacity to 234,000 t/yr from 120,000 t/yr, and Alcan's share would increase to 63,000 t/yr from 34,000 t/yr. The increased capacity was expected to come onstream in 2007 (Alcan Inc., 2005f).

In July, Alcan and members of the Canadian Auto Workers Local 2301 ratified a new 3-year labor agreement covering workers at the Kitimat, British Columbia, smelter (Alcan Inc., 2005c).

China.—Shanghai Sigma Metals Inc. announced plans to increase production at its new secondary aluminum smelter by the end of 2006 to 300,000 t/yr from about 140,000 t/yr in 2005. Shanghai Sigma's goal was to increase ingot production by another 120,000 t/yr in a second stage expansion by 2010 (Foster, 2005).

France.—Alcan began discussions with workers as part of the planned progressive closure of its 50,000-t/yr Lannemezan smelter. The closure process was expected to begin by June 2006 and would be completed during 2008, depending on economic and operational conditions (Alcan Inc., 2005j).

Germany.—As part of a restructuring of its primary aluminum plants owing to increased power costs, Norsk Hydro announced the closure of its 130,000-t/yr smelter and carbon plant at Hamburger Aluminium Werk GmbH (HAW) by yearend and the permanent closure of its 70,000-t/yr smelter in Stade by the end of 2006. Norsk Hydro planned to keep the HAW casthouse operating to supply the nearby rolling mill (Norsk Hydro ASA, 2005).

VAW-Imco Guss und Recycling GmbH (a subsidiary of Aleris) opened its newest secondary aluminum smelter having an initial capacity of 60,000 t/yr. The facility in Stuttgart could be expanded to 120,000 t/yr if needed (Mason, 2005).

Ghana.—Alcoa and the Government of Ghana finalized an agreement to restart Volta Aluminium Co.'s (Valco) 200,000-t/yr aluminum smelter in Tema. The smelter has beed closed since April 2003. Plans were underway to restart three of the five potlines at Valco representing 120,000 t/yr of capacity. Alcoa and the Government continued discussions on the development of an integrated aluminum industry in Ghana that included bauxite mining, alumina refining, aluminum production, and rail transportation infrastructure upgrades (Alcoa Inc., 2005e).

Hungary.—Alcoa announced an $83 million modernization project at Alcoa-Kofem Ltd. The modernization includes the expansion of flat-rolled mill products capability and related infrastructure, the addition of Dura-Bright® aluminum wheel production, and a new manufacturing operation for airfoil castings (Alcoa Inc., 2005a).

Iceland.—Century announced that its subsidiary, Nordural ehf, had obtained sufficient electricity to accelerate the

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expansion of its primary aluminum smelter to 220,000 t/yr by mid-to-late 2006 rather than the 2007 timeframe that had been announced previously (Century Aluminum Co., 2005b).

Century also announced that Nordural had signed an agreement with a major Icelandic geothermal power producer, Hitaveita Sudurnesja hf., and the municipality of Reykjanesbaer to explore the feasibility of constructing a new aluminum smelter in Helguvik or at a mutually agreeable site. If the project goes forward, startup would be targeted for 2010 to 2015 (Century Aluminum Co., 2005c).

India.—Vedanta Resources plc approved a $2.1 billion aluminum project in Jharsuguda, Orissa. The project included a 500,000-t/yr primary aluminum smelter and a captive powerplant. The smelter would be built in two phases of 250,000 t/yr each. Construction was expected to begin in 2006 with completion of phase 1 expected by mid-2009, and phase 2, by yearend 2010. Alumina for the smelter would be provided by Vedanta's 1-Mt/yr greenfield refinery in Orissa, which was scheduled to be commissioned in 2007 (American Metal Market, 2005).

In addition to the Vedanta project, several other projects were under discussion. Hindalco Industries Ltd. reported the signing of an MOU with the State government of Orissa for an integrated aluminum project that included a 260,000-t/yr smelter, a 1-Mt/yr alumina refinery, a captive powerplant, and bauxite mines with a capacity of 3 Mt/yr (Metal Bulletin, 2005b). Jindal South West Holdings Ltd. (a subsidiary of the steel conglomerate O.P. Jindal Group) announced plans to invest in a new aluminum complex in the State of Andhra Pradesh. The plans included a 1.5-Mt/yr alumina refinery, a 250,000-t/yr smelter, and a powerplant. The State mining company, Andhra Pradesh Mineral Development Corp., was expected to provide bauxite for the project (Metal Bulletin, 2005c). Dubai Aluminum Company Ltd. (Dubal) and Larsen & Toubro Ltd. signed a $3.6 billion agreement for the development of an integrated aluminum complex in Orissa. The first phase included a bauxite mine and a 1.5-Mt/yr alumina refinery. Phase 2 would double the size of the refinery and add an aluminum smelter (CRU Alumina Monitor, 2005a).

Iran.—Announced expansions at the country's two aluminum smelters and an announced agreement to build a greenfield plant in the southern portion of the country would increase Iran's smelter capacity to 780,000 t/yr from 230,000 t/yr. Iranian Aluminium Co. (Iralco) planned to expand its smelter in Arak to 180,000 t/yr from 120,000 t/yr. Almahdi Aluminium Corp. announced a two-phase expansion of its 110,000-t/yr smelter in Bandar Abbas. Each phase would add 110,000 t/yr of capacity increasing the smelter's capacity to 330,000 t/yr by 2009 (Metal Bulletin, 2005d). China's Citic Group and a subsidiary of Aluminium Corp. of China (Chalco) were awarded a $900 million contract to build the first phase of a smelter for Iran's South Aluminium Corp. in Tehran. Phase one included a 270,000-t/yr smelter, a 150,000-t/yr anode plant, and port facilities (Metal Bulletin, 2005a).

Japan.—Two of Japan's leading producers of aluminum cans have merged. The new venture would be owned by Mitsubishi Materials Corp. (80%), Japan's leading maker of aluminum cans with a production capacity of 3.7 billion cans per year, and Hokkai Can Co. Ltd. (20%), which produces about 1.3 billion aluminum cans per year, 1.4 billion steel cans per year, and 1 billion polyethylene terephthalate (PET) bottles per year (McCulloch, 2005).

Kazakhstan.—The joint-venture agreement signed in 2004 between RUSAL and Eurasian Financial-Industrial Co. was suspended. The original agreement included the construction of a 1.5-Mt/yr alumina refinery and a 500,000-t/yr aluminum smelter in northern Kazakhstan (Kassakovich, 2005).

Norway.—In January, Orkla ASA increased its holdings in Elkem ASA to 50.03% and subsequently launched a program to purchase all of the remaining shares in the company. In March, Alcoa announced the sale of its 46.5% stake in Elkem to Orkla for $870 million. Alcoa's 50% interest in the Mosjoen and Lista aluminum smelters (co-owned with Elkem) was not included in the sale (Alcoa Inc., 2005n).

To meet new emission standards, Norsk Hydro announced plans to close the 22,000-t/yr Soderberg potline at its 77,000-t/yr Hoyanger smelter and the 48,000-t/yr Soderberg potline at its 220,000-t/yr Ardal smelter. The closures were expected to be completed by yearend 2006 (Norsk Hydro ASA, 2005).

Norsk Hydro announced plans to expand the casthouse capacity at its Sunndal smelter. The company planned to build a new 80,000-t/yr casting center for foundry alloys to help meet the increased demand from the automotive industry. The Sunndal casthouse also produced extrusion ingots (Platts Metals Week, 2005c).

Oman.—Alcan announced that it would construct a $1.7 billion primary aluminum smelter in Sohar with partners Oman Oil Company S.A.O.C. and the Abu Dhabi Water and Electricity Authority. Alcan would take a 20% stake in the 350,000-t/yr smelter, which was expected to begin production in the third quarter of 2008. The smelter's initial capacity would be from a single AP35 potline, but with provisions for a second potline, of which Alcan would be eligible to acquire up to 60% of production. In addition to casting and carbon facilities, a gas-fired powerplant would also be constructed to give the smelter a long-term dedicated power supply sufficient to meet its energy requirements (Alcan Inc., 2005e).

Romania.—S.C. Alro S. A. announced plans to increase capacity at its 240,000-t/yr smelter in Slatina to 420,000 t/yr by 2008. The company also planned to increase capacity to 120,000 t/yr from 45,000 t/yr during the same timeframe to make value-added products at its subsidiary, Alprom S.A., which produced aluminum alloys, cast products, and rolled products (Marco Group GmbH, 2005§).

Russia.—RUSAL invested $250 million in the construction of the Khakass aluminum smelter. The 300,000-t/yr plant was expected to produce its first metal by yearend 2006 (RUSAL, 2006).

ALSTOM signed a contract with RUSAL to supply 12 dry gas scrubbing units to RUSAL's 865,000-t/yr Krasnoyarsk smelter. The new scrubbers, which would capture hydrogen fluoride and dust emissions, were part of an extensive modernization program at the smelter that would increase capacity by about 55,000 t/yr (RUSAL, 2005d). At yearend, five of the scrubbers and eight automated alumina feeders had been installed at the smelter (RUSAL, 2006).

RAO Unified Energy Systems and RUSAL signed a basic conditions of partnership agreement covering the construction of

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the Boguchanskaya hydropower plant and a greenfield 600,000-t/yr primary aluminum smelter in the Krasnoyarsk region. Preliminary estimates put the total cost of the project at more than $4 billion. The feasibility study for the aluminum smelter was expected to be completed in 2006, and the entire project could take 7 years to complete (RUSAL, 2005b).

Alcan announced plans to invest $55 million to construct new packaging plants in Moscow and St. Petersburg. The Moscow facility would focus on flexible packaging for the confectionary and dairy markets, and the St. Petersburg facility would be dedicated to producing packaging for the tobacco industry (Alcan Inc., 2005m). Ground was broken at the St. Petersburg site in December, and production was expected to begin by yearend 2006 (Alcan Inc., 2005d).

Serbia and Montenegro.—Salamon Enterprises (a subsidiary of RUSAL) purchased a 65.4% stake in Kombinat Aluminijuma Podgorica, which operated a 125,000-t/yr aluminum smelter and a 280,000-t/yr alumina refinery in Podgorica (CRU Alumina Monitor, 2005b).

Slovakia.—Alcan announced plans to invest $35 million in a new aluminum extrusion plant in Slovakia to produce profiles for the building and construction sectors in Eastern Europe. The facility would have two aluminum extrusion press lines. Pending final approval from local authorities, production was expected to start in early 2007 (Alcan Inc., 2005l).

Tajikistan.—RUSAL and the Ministry of Energy selected Lahmeyer International of Germany to produce a bankable feasibility study for completion of the Rogunskaya hydroelectric project in Dushanbe. Construction of the powerplant was part of an October 2004 agreement between RUSAL and the Tajik Government on cooperation in the energy and the aluminum industries. Initial construction of the hydropower plant in Dushanbe began in 1976 but was subsequently suspended. The new target date for completion was 2010 (RUSAL, 2005a).

United Arab Emirates.—In Dubai, Dubal fully commissioned the recent expansion of potline 7, which increased capacity at its primary aluminum smelter to 761,000 t/yr of aluminum metal. SNC-Lavalin Group Inc. was awarded a $284 million contract for the expansion of two existing potlines that would increase capacity at the smelter an additional 100,000 t/yr by the end of 2006 (Platts Metals Week, 2005b).

United Kingdom.—Novelis Inc. completed a $2.5 million infrastructure investment at its Warrington recycling plant that increased the plant's aluminum UBC recycling capacity by 25%. The facility recycled 6 billion UBCs during the first 9 months of 2005, establishing a new plant recycling record. Novelis, which was spun off by Alcan in January, is a global leader in aluminum rolled products and aluminum can recycling with 36 operating facilities in 11 countries (Novelis Inc., 2005).

Outlook

World demand for aluminum was expected to increase during the next few years but at a slightly slower pace than that of the past year or two. Demand from China was expected to continue to be the major driving force behind this increase. Although growth in the transportation and construction industries may slow somewhat, these industries will continue to dominate the aluminum market. Energy costs have always been an important factor in determining the location of primary aluminum smelters. This is especially true in this era of high energy costs and, in some areas, limited energy supply. New smelters are being built near inexpensive or renewable sources of energy. Recently completed and announced expansions are expected to be adequate to meet future world demand.

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TABLE 1
SALIENT ALUMINUM STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Primary production:						
Quantity	thousand metric tons	2,637	2,707	2,703	2,516	2,481
Value	millions	$4,000	$3,870	$4,060	$4,660	$4,980
Price, average, U.S. market, spot	cents per pound	68.8	64.9	68.1	84.0	91.0
Inventories (December 31):						
Aluminum industry[2]	thousand metric tons	1,300	1,320	1,400	1,470	1,430
LME stocks in U.S. warehouses[3]	do.	28	45	207	116	209
Secondary recovery:[4]						
New scrap	do.	1,760	1,750	1,750	1,870	1,930
Old scrap	do.	1,210	1,170	1,070	1,160	1,060
Total	do.	2,970	2,930	2,820	3,030	2,990
Exports, crude and semicrude	do.	1,590	1,590	1,540	1,820	2,370
Imports for consumption, crude and semicrude	do.	3,740	4,060	4,130	4,720	5,330
Supply, apparent[5]	do.	7,990	8,070	7,880	8,460	8,390
Consumption, apparent[6]	do.	6,230	6,320	6,130	6,590	6,460
World, production	do.	24,300	26,100	28,000 r	29,900 r	31,900 e

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits except "Primary production."

[2]Data from the Aluminum Association Inc.; includes ingot, semifabricated material, and scrap. Beginning in 2003, data series revised to include inventory levels for both United States and Canadian producers.

[3]Includes aluminum alloyed material.

[4]Metallic recovery from purchased, tolled, or imported new and old scrap expanded for full industry coverage.

[5]Defined as domestic primary metal production plus secondary recovery plus imports minus exports plus adjustments for Government and industry stock changes.

[6]Apparent supply less recovery from purchased new scrap.

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TABLE 2

PRIMARY ANNUAL ALUMINUM PRODUCTION CAPACITY IN THE UNITED STATES, BY COMPANY[1]

Company and location	Yearend capacity (thousand metric tons) 2004	2005	2005 ownership
Alcan Aluminum Corp., Sebree, KY	196	196	Alcan Inc., 100%.
Alcoa Inc.:			
Alcoa, TN	215	215	Alcoa Inc., 100%.
Badin, NC	120	120	Do.
Evansville, IN (Warrick)	309	309	Do.
Ferndale, WA (Intalco)	278	278	Alcoa Inc., 61%; Mitsui & Co. Ltd., 39%.
Frederick, MD (Eastalco)	195	195	Do.
Massena, NY (St. Lawrence)	125	125	Alcoa Inc., 100%.
Massena, NY	130	130	Do.
Mount Holly, SC	224	224	Alcoa Inc., 50.3%; Century Aluminum Co., 49.7%.
Rockdale, TX	267	267	Alcoa Inc., 100%.
Wenatchee, WA	184	184	Do.
Total	2,050	2,050	
Century Aluminum Co.:			
Hawesville, KY	244	244	Century Aluminum Co., 100%.
Ravenswood, WV	170	170	Do.
Total	414	414	
Columbia Falls Aluminum Co., Columbia Falls, MT	168	168	Glencore International AG, 100%.
Goldendale Aluminum Co., Goldendale, WA	160	160	Private interest, 60%; employees, 40%.
Noranda Aluminum Inc., New Madrid, MO	250	250	Falconbridge Ltd., 100%.
Northwest Aluminum Corp., The Dalles, OR	82	82	Private interest, 100%.
Ormet Primary Aluminum Corp., Hannibal, OH	265	265	Ormet Corp., 100%.
Vanalco Inc., Vancouver, WA	116	116	Glencore International AG, 100%.
Grand total	3,700	3,700	

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 3

U.S. CONSUMPTION OF AND RECOVERY FROM PURCHASED NEW AND OLD ALUMINUM SCRAP, BY CLASS[1, 2]

(Metric tons)

Class	Calculated recovery Consumption	Aluminum	Metallic
2004:			
Secondary smelters	1,630,000	1,130,000	1,210,000
Integrated aluminum companies	754,000	628,000	668,000
Independent mill fabricators	904,000	790,000	844,000
Foundries	91,600	76,200	81,400
Other consumers	8,210	7,340	7,360
Total	3,390,000	2,630,000	2,810,000
Estimated full industry coverage	3,650,000	2,830,000	3,030,000
2005:			
Secondary smelters	1,550,000	1,110,000	1,190,000
Integrated aluminum companies	815,000	681,000	725,000
Independent mill fabricators	842,000	739,000	789,000
Foundries	82,000	67,700	72,300
Other consumers	8,640	7,810	7,830
Total	3,300,000	2,610,000	2,780,000
Estimated full industry coverage	3,540,000	2,800,000	2,990,000

[1]Excludes recovery from other than aluminum-base scrap.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 4

U.S. STOCKS, RECEIPTS, AND CONSUMPTION OF PURCHASED NEW AND OLD ALUMINUM SCRAP AND SWEATED PIG IN 2005[1, 2]

(Metric tons)

Class of consumer and type of scrap	Stocks, January 1	Net receipts[3]	Consumption	Stocks, December 31
Secondary smelters:				
New scrap:				
Extrusions	14,000	282,000	288,000	8,280
Can stock clippings	1,960	73,000	74,700	163
Other wrought sheet and clippings	948	175,000	175,000	1,410
Casting	1,270	76,000	75,600	1,740
Borings and turnings	3,480	158,000	154,000	7,220
Dross and skimmings	4,940	372,000	372,000	4,000
Total	26,600	1,140,000	1,140,000	22,800
Old scrap:				
Castings	4,000	188,000	187,000	4,950
Extrusion	73	17,400	17,400	80
Aluminum cans[4]	386	44,700	44,900	139
Other wrought products	1,690	19,500	21,100	98
Auto shredder scrap	2,420	130,000	129,000	3,760
Total	8,570	400,000	399,000	9,030
Sweated pig	289	9,390	9,490	198
Grand total, secondary smelters	35,400	1,540,000	1,550,000	32,000
Integrated aluminum companies, foundries, independent mill fabricators, other consumers:				
New scrap:				
Extrusion	6,810	604,000	597,000	13,500
Can stock clippings	2,780	237,000	239,000	916
Other wrought sheet and clippings	3,980	103,000	104,000	3,120
Casting	240	27,300	27,300	240
Borings and turnings	361	16,600	16,600	361
Dross and skimmings	250	7,540	7,620	168
Total	14,400	996,000	992,000	18,300
Old scrap:				
Castings	1,630	25,900	26,600	889
Extrusion	--	3,640	3,590	55
Aluminum cans[4]	4,180	653,000	657,000	444
Other wrought products	2,400	68,000	68,000	2,400
Auto shredder scrap	24	648	620	52
Total	8,230	751,000	755,000	3,840
Sweated pig	15	595	609	1
Grand total, integrated aluminum companies, etc.	22,700	1,750,000	1,750,000	22,200
All scrap consumed:				
New scrap:				
Extrusion	20,800	886,000	885,000	21,800
Can stock clippings	4,740	310,000	314,000	1,080
Other wrought sheet and clippings	4,930	278,000	278,000	4,540
Casting	1,510	103,000	103,000	1,980
Borings and turnings	3,840	175,000	171,000	7,580
Dross and skimmings	5,190	379,000	380,000	4,160
Total	41,000	2,130,000	2,130,000	41,200

See footnotes at end of table.

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TABLE 4—Continued
U.S. STOCKS, RECEIPTS, AND CONSUMPTION OF PURCHASED NEW AND OLD ALUMINUM SCRAP AND SWEATED PIG IN 2005[1, 2]

(Metric tons)

Class of consumer and type of scrap	Stocks, January 1	Net receipts[3]	Consumption	Stocks, December 31
All scrap consumed—Continued:				
Old scrap:				
Castings	5,630	214,000	214,000	5,840
Extrusion	73	21,100	21,000	135
Aluminum cans	4,560	697,000	701,000	583
Other wrought products	4,090	87,500	89,100	2,490
Auto shredder scrap	2,450	131,000	129,000	3,810
Total	16,800	1,150,000	1,150,000	12,900
Sweated pig	304	9,990	10,100	198
Grand total, all scrap consumed	58,100	3,290,000	3,300,000	54,200

-- Zero.

[1]Includes imported scrap. According to reporting companies, 12.5% of total receipts of aluminum-base scrap, or 416,000 metric tons, was received on toll arrangements.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Includes inventory adjustment.

[4]Used beverage cans toll treated for primary producers are included in secondary smelter tabulation.

TABLE 5
PRODUCTION AND SHIPMENTS OF SECONDARY ALUMINUM ALLOYS BY INDEPENDENT SMELTERS IN THE UNITED STATES[1]

(Metric tons)

	2004		2005	
	Production	Net shipments[2]	Production	Net shipments[2]
Diecast alloys:				
13% Si, 360, etc. (0.6% Cu, maximum)	18,400	18,700	20,300	17,500
380 and variations	270,000	270,000	199,000	199,000
Sand and permanent mold:				
95/5 Al-Si, 356, etc. (0.6% Cu, maximum)	49,200	49,700	19,400	19,400
No. 12 and variations	--	15	1,670	1,650
No. 319 and variations	123,000	124,000	74,000	73,900
F-132 alloy and variations	26,000	26,400	22,600	22,500
Al-Mg alloys	1,490	1,300	19,400	19,700
Al-Zn alloys	2,020	2,110	2,370	2,210
Al-Si alloys (0.6% to 2.0% Cu)	551	551	291	289
Al-Cu alloys (1.5% Si, maximum)	3,910	3,910	5,180	4,940
Al-Si-Cu-Ni alloys	--	1	483	480
Other	236	257	6,850	6,820
Wrought alloys, extrusion billets	290,000	288,000	301,000	267,000
Miscellaneous:				
Steel deoxidation	24,600	25,000	18,100	18,100
Pure (97.0% Al)	W	W	W	W
Aluminum-base hardeners	W	W	W	W
Other[3]	53,600	52,300	48,200	49,600
Total	863,000	862,000	739,000	704,000

See footnotes at end of table.

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TABLE 5—Continued
PRODUCTION AND SHIPMENTS OF SECONDARY ALUMINUM ALLOYS BY INDEPENDENT SMELTERS IN THE UNITED STATES[1]

(Metric tons)

	2004		2005	
	Production	Net shipments[2]	Production	Net shipments[2]
Less consumption of materials other than scrap:				
Primary aluminum	122,000	XX	144,000	XX
Primary silicon	36,500	XX	26,800	XX
Other	6,800	XX	6,970	XX
Net metallic recovery from aluminum scrap and sweated pig consumed in production of secondary aluminum ingot[4]	697,000	XX	561,000	XX

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous, other." XX Not applicable.
-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes inventory adjustment.
[3]Includes other diecast alloys.
[4]No allowance made for melt loss of primary aluminum and alloying ingredients.

TABLE 6
DISTRIBUTION OF END-USE SHIPMENTS OF ALUMINUM PRODUCTS IN THE UNITED STATES AND CANADA, BY INDUSTRY[1]

	2004		2005[p]	
Industry	Quantity (thousand metric tons)	Percentage of grand total	Quantity (thousand metric tons)	Percentage of grand total
Containers and packaging	2,310	20.4 [r]	2,320	21.0
Building and construction	1,680	14.8	1,680	15.2
Transportation	3,860	34.0 [r]	3,940	35.6
Electrical	720 [r]	6.3 [r]	752	6.8
Consumer durables	713 [r]	6.3 [r]	708	6.4
Machinery and equipment	730	6.4	755	6.8
Other markets	416	3.7	424	3.8
Total	10,400 [r]	91.8	10,600	95.6
Exports[e]	930 [r]	8.2	484	4.4
Grand total	11,400	100.0	11,100	100.0

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: The Aluminum Association Inc.

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TABLE 7
U.S. NET SHIPMENTS OF ALUMINUM WROUGHT AND CAST PRODUCTS, BY PRODUCERS[1, 2, 3]

(Thousand metric tons)

	2003	2004	2005[p]
Wrought products:			
Sheet, plate, foil	4,370 r	4,750 r	4,680
Pipe, tube, extruded shapes	1,670 r	1,810 r	1,900
Rod, bar, wire, cable	368 r	397 r	406
Forgings (including impacts)	107 r	121 r	129
Powder, flake, paste	56	61	55
Total	6,580 r	7,140 r	7,160
Castings:			
Sand	285 r	221 r	287
Permanent and semipermanent mold	719 r	735 r	780
Die	1,210	1,250 r	1,100
Other	189 r	161 r	107
Total	2,400 r	2,370 r	2,280
Grand total	8,970 r	9,510 r	9,440

[p]Preliminary. [r]Revised.

[1]Net shipments derived by subtracting the sum of producers' domestic receipts of each mill shape from the domestic industry's gross shipments of that shape.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Wrought products data series includes net shipments in both the United States and Canada.

Source: The Aluminum Association Inc.

TABLE 8
U.S. EXPORTS OF ALUMINUM, BY COUNTRY[1]

	Metals and alloys, crude		Plates, sheets, bars, etc.[2]		Scrap		Total	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
2004:								
Azerbaijan	--	--	3	$20	--	--	3	$20
Brazil	1,120	$2,470	11,600	50,800	78	$126	12,800	53,300
Canada	132,000	250,000	523,000	1,470,000	142,000	186,000	797,000	1,910,000
China	454	1,220	36,200	100,000	314,000	321,000	350,000	423,000
France	124	586	6,220	47,900	176	322	6,520	48,800
Germany	439	1,460	4,640	34,900	245	407	5,320	36,800
Hong Kong	95	516	9,180	32,200	10,800	16,000	20,000	48,700
Italy	228	502	2,060	14,000	42	47	2,330	14,600
Japan	5,170	14,900	7,400	71,900	23,300	32,900	35,900	120,000
Kazakhstan	--	--	55	331	--	--	55	331
Korea, Republic of	809	3,290	16,500	77,500	54,300	70,800	71,600	152,000
Mexico	150,000	267,000	162,000	490,000	38,100	56,000	350,000	812,000
Netherlands	365	1,370	744	4,830	222	588	1,330	6,790
Philippines	--	--	142	1,150	--	--	142	1,150
Russia	5	21	27	381	--	--	32	402
Saudi Arabia	29	215	17,400	42,200	(3)	3	17,400	42,500
Singapore	215	1,290	1,680	16,200	362	234	2,260	17,700
South Africa	1	12	223	2,010	--	--	224	2,030
Taiwan	641	1,600	5,900	25,300	39,200	49,200	45,700	76,100

See footnotes at end of table.

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TABLE 8—Continued
U.S. EXPORTS OF ALUMINUM, BY COUNTRY[1]

Country	Metals and alloys, crude		Plates, sheets, bars, etc.[2]		Scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
2004—Conitnued:								
Tajikstan	--	--	84	661	--	--	84	661
Thailand	172	678	5,090	20,600	4,920	5,720	10,200	27,000
Ukraine	--	--	(3)	14	--	--	(3)	14
United Kingdom	833	3,450	11,700	86,500	165	294	12,700	90,200
Venezuela	20	78	1,650	6,560	3	30	1,670	6,670
Other	5,530	14,600	34,600	196,000	32,200	33,200 r	72,300	244,000
Total	298,000	565,000	857,000	2,790,000	660,000	773,000	1,820,000	4,130,000
2005:								
Azerbaijan	--	--	2	24	--	--	2	24
Brazil	226	732	8,070	37,800	1,620	2,390	9,920	40,900
Canada	128,000	261,000	487,000	1,540,000	146,000	203,000	761,000	2,000,000
China	491	1,890	41,600	158,000	581,000	703,000	623,000	862,000
France	838	2,350	9,100	64,000	48	101	9,990	66,500
Germany	859	6,460	8,400	55,900	306	499	9,570	62,900
Hong Kong	236	568	7,480	33,100	11,200	17,700	18,900	51,400
Italy	177	500	3,170	22,600	(3)	4	3,350	23,100
Japan	4,520	19,000	10,700	110,000	34,900	51,600	50,100	181,000
Kazakhstan	--	--	7	797	--	--	7	797
Korea, Republic of	1,070	3,410	12,800	71,500	131,000	161,000	145,000	236,000
Mexico	184,000	342,000	232,000	697,000	75,200	109,000	490,000	1,150,000
Netherlands	131	1,380	685	5,130	103	237	919	6,750
Philippines	1	5	198	1,760	773	841	971	2,610
Russia	154	526	65	395	26	80	245	1,000
Saudi Arabia	8	18	31,100	77,000	--	--	31,100	77,000
Singapore	356	1,110	2,490	15,900	658	365	3,510	17,400
South Africa	1	9	312	3,400	--	--	314	3,410
Taiwan	360	1,780	9,320	42,500	48,400	66,700	58,100	111,000
Thailand	402	1,930	7,950	30,900	5,500	7,520	13,800	40,300
Ukraine	--	--	1	31	--	--	1	31
United Kingdom	329	2,700	17,300	122,000	469	1,070	18,100	126,000
Venezuela	12	91	1,790	7,110	21	87	1,820	7,280
Other	7,480	18,200	59,900	273,000	49,700	49,600	117,000	341,000
Total	329,000	666,000	951,000	3,370,000	1,090,000	1,370,000	2,370,000	5,410,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes castings, forgings, and unclassified semifabricated forms.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 9
U.S. EXPORTS OF ALUMINUM, BY CLASS[1]

Class	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	298,000	$565,000	329,000	$666,000
Scrap	660,000	773,000	1,090,000	1,370,000
Plates, sheets, bars, strip, etc.	795,000	2,380,000	886,000	2,910,000
Castings and forgings	21,900	175,000	25,700	216,000
Semifabricated forms, n.e.c.	40,100	237,000	39,500	247,000
Total	1,820,000	4,130,000	2,370,000	5,410,000
Manufactures:				
Foil and leaf	85,000	287,000	87,000	320,000
Powders and flakes	12,300	53,500	9,430	46,500
Wire and cable	32,200	96,500	38,800	115,000
Total	129,000	437,000	135,000	482,000
Grand total	1,950,000	4,570,000	2,500,000	5,890,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM, BY CLASS[1]

Class	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	3,250,000	$5,880,000	3,660,000	$7,140,000
Plates, sheets, strip, etc., n.e.c.[2]	724,000	1,950,000	927,000	2,710,000
Pipes, tubes, etc.	34,900	171,000	32,800	181,000
Rods and bars	179,000	581,000	232,000	774,000
Scrap	535,000	655,000	482,000	658,000
Total	4,720,000	9,240,000	5,330,000	11,500,000
Manufactures:				
Foil and leaf[3]	107,000	378,000	136,000	506,000
Powders and flakes	5,360	18,700	6,320	25,800
Wire	175,000	359,000	195,000	432,000
Total	288,000	756,000	337,000	964,000
Grand total	5,010,000	10,000,000	5,670,000	12,400,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes circles, disks, plates, and sheets.
[3]Excludes etched capacitor foil.

Source: U.S. Census Bureau.

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TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM, BY COUNTRY[1]

Country	Metals and alloys, crude		Plates, sheets, bars, etc.[2]		Scrap		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
2004:								
Argentina	75,400	$115,000	583	$2,220	204	$259	76,200	$118,000
Australia	65,100	123,000	87	1,340	35	39	65,200	124,000
Bahrain	2,670	4,910	13,100	29,600	--	--	15,800	34,500
Belgium	688	1,220	11,600	32,100	--	--	12,300	33,300
Brazil	226,000	399,000	31,700	77,000	4,770	8,950	262,000	485,000
Canada	1,660,000	3,070,000	489,000	1,340,000	353,000	422,000	2,500,000	4,830,000
China	13,900	25,000	52,800	159,000	230	352	67,000	184,000
France	2,610	10,500	7,770	32,300	271	388	10,600	43,100
Germany	4,380	13,400	81,500	291,000	933	932	86,800	306,000
Italy	450	776	2,030	11,700	--	--	2,480	12,500
Japan	1,750	4,220	12,100	57,600	569	1,990	14,500	63,900
Korea, Republic of	68	308	3,380	13,400	29	37	3,480	13,800
Mexico	1,260	2,510	21,400	73,000	84,700	103,000	107,000	179,000
Netherlands	1,110	2,990	2,840	15,900	229	657	4,180	19,600
Norway	4,110	9,000	121	510	5	9	4,240	9,520
Panama	--	--	404	1,350	3,220	4,090	3,620	5,440
Russia	904,000	1,590,000	37,600	90,500	9,860	15,100	952,000	1,690,000
Slovenia	--	--	4,930	15,400	--	--	4,930	15,400
South Africa	40,000	69,300	36,100	87,500	--	--	76,100	157,000
Spain	114	362	1,730	6,820	--	--	1,850	7,180
Ukraine	--	--	--	--	57	155	57	155
United Arab Emirates	54,300	102,000	79	254	487	652	54,800	103,000
United Kingdom	6,340	12,800	2,870	19,400	4,360	5,590	13,600	37,800
Venezuela	138,000	239,000	19,900	37,800	20,300	27,900	178,000	304,000
Other	46,200	86,800	104,000	315,000	52,300	62,600	203,000	465,000
Total	3,250,000	5,880,000	938,000	2,710,000	535,000	655,000	4,720,000	9,240,000
2005:								
Argentina	65,600	126,000	2,980	7,490	--	--	68,600	134,000
Australia	63,200	132,000	134	1,650	1,300	2,620	64,600	137,000
Bahrain	22,700	46,600	15,500	38,600	--	--	38,200	85,200
Belgium	36	152	13,100	41,300	28	35	13,200	41,500
Brazil	194,000	367,000	34,200	96,500	126	243	228,000	464,000
Canada	1,920,000	3,750,000	514,000	1,500,000	310,000	424,000	2,740,000	5,680,000
China	68,200	136,000	121,000	345,000	247	454	190,000	481,000
France	789	7,570	6,340	33,600	99	162	7,220	41,300
Germany	2,400	7,920	114,000	413,000	334	447	116,000	421,000
Italy	757	3,410	2,860	16,200	--	--	3,620	19,600
Japan	536	1,750	20,400	89,800	521	1,950	21,500	93,500
Korea, Republic of	87	437	2,810	12,800	--	--	2,900	13,200
Mexico	97	187	22,400	82,800	105,000	143,000	127,000	226,000
Netherlands	436	1,580	2,660	14,000	79	92	3,170	15,600
Norway	4,060	7,940	111	524	2	29	4,180	8,490
Panama	39	66	464	1,650	3,590	5,260	4,100	6,970
Russia	819,000	1,570,000	55,100	160,000	6,830	12,500	880,000	1,740,000
Slovenia	--	--	4,000	13,100	--	--	4,000	13,100
South Africa	77,700	149,000	52,100	152,000	--	--	130,000	301,000
Spain	79	279	3,100	8,050	106	203	3,280	8,530
Tajikstan	127,000	239,000	--	--	--	--	127,000	239,000
United Arab Emirates	79,100	164,000	576	1,450	718	1,170	80,400	166,000
United Kingdom	22,600	45,800	7,410	32,800	2,470	3,380	32,500	81,900
Venezuela	145,000	280,000	11,200	24,400	8,950	12,100	165,000	317,000
Other	49,200	105,000	185,000	581,000	41,100	50,500	276,000	736,000
Total	3,660,000	7,140,000	1,190,000	3,670,000	482,000	658,000	5,330,000	11,500,000

See footnotes at end of table.

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TABLE 11—Continued
U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM, BY COUNTRY[1]

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes circles, disks, pipes, rods, tubes, etc.

Source: U.S. Census Bureau.

TABLE 12
ALUMINUM, PRIMARY: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country	2001	2002	2003	2004	2005[e]
Argentina	245	269	272	272 [r]	271
Australia	1,797	1,836	1,857	1,894 [r]	1,903 [3]
Azerbaijan	--	--	19	30 [e]	30
Bahrain	523	519	532	532 [r]	751 [3]
Bosnia and Herzegovina[4]	95 [r]	102 [r]	113 [r]	121 [r]	131 [3]
Brazil	1,140	1,318	1,381	1,457	1,499 [3]
Cameroon	81	67	77	86 [r]	90 [3]
Canada	2,583	2,709	2,792	2,592	2,894 [3]
China[e]	3,250	4,300	5,450	6,670	7,800
Croatia[4]	16	--	--	-- [e]	--
Egypt	191	195	195	216 [r]	244 [3]
France	462	463	443	451 [r]	442 [3]
Germany	652	653	661	668 [r]	668
Ghana	144	117	16 [r]	-- [e]	13 [3]
Greece	166	165	165	167 [r]	165
Hungary[e]	34	35	35	35	35
Iceland[5]	242 [r]	285 [r]	286 [r]	271	272 [3]
India[6]	624	671	799	862	898 [3]
Indonesia[e, 6]	180	160	200	230	240
Iran	146 [r]	169	182 [r]	213 [r]	220
Italy	187	190	191	195 [r]	195
Japan[7]	7	6	6 [r]	6	7
Mexico[6]	52	39	--	-- [e]	--
Mozambique	270 [r]	268 [r]	409 [r]	549 [r]	555 [3]
Netherlands	294	284	283 [r]	326	325
New Zealand	322	335 [e]	340 [e]	350	351 [3]
Norway	1,068	1,096	1,192	1,322	1,372 [3]
Poland[8]	45	49	45	46 [r]	43 [3]
Romania[9]	182	187	197 [r]	219 [r]	244 [3]
Russia	3,300	3,347	3,478	3,592 [r]	3,647 [3]
Serbia and Montenegro[4]	100	112	112	115 [e]	115
Slovakia[6]	134	147	165	160 [e]	160
Slovenia[4]	77	88	110	121 [r]	139
South Africa	662	707	738	863	851
Spain	376	380	389	398	395
Sweden	102	101	101	101	102 [3]
Switzerland	36	40	44	45	45
Tajikistan	289	308	319	358	380 [3]
Turkey[e]	62 [3]	63 [3]	63	60	60

See footnotes at end of table.

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TABLE 12—Continued

ALUMINUM, PRIMARY: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country	2001	2002	2003	2004	2005[e]
Ukraine[9]	106	112	114	113	114 [3]
United Arab Emirates, Dubai[e]	500	536	560 [3]	683 [3]	750
United Kingdom	341	344	343	360	360
United States	2,637	2,707	2,703	2,516	2,481 [3]
Venezuela	571	605	601	624	610
Total	24,300	26,100	28,000 [r]	29,900 [r]	31,900

[e]Estimated. [r]Revised. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Primary aluminum is defined as "The weight of liquid aluminum as tapped from pots, excluding the weight of any alloying materials as well that of any metal produced from either returned scrap or remelted materials." International reporting practices vary from country to country, some nations conforming to the foregoing definition and others using different definitions. For those countries for which a different definition is given specifically in the source publication, that definition is provided in this table by footnote. Table includes data available through May 5, 2006.

[3]Reported figure.

[4]Primary ingot plus secondary ingot.

[5]Ingot and rolling billet production.

[6]Primary ingot.

[7]Excludes high purity aluminum containing 99.995% or more as follows, in metric tons: 2001—26,586; 2002—40,443; 2003—43,697 (revised); 2004—55,402 (revised); and 2005—47,000 (estimated).

[8]Primary unalloyed ingot plus secondary unalloyed ingot.

[9]Primary unalloyed metal plus primary alloyed metal, thus including weight of alloying material.

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ANTIMONY

James F. Carlin, Jr.

Domestic survey data and tables were prepared by Mahbood Mahdavi, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

There was no domestic antimony mine production during the year. Most domestic smelting consisted of upgrading imported antimony trioxide to a higher purity. Most primary antimony metal and antimony oxide were produced domestically from imported raw material. Primary antimony metal and antimony oxide were produced by one company in Montana. Secondary antimony was recovered in lead alloy from scrapped lead-acid batteries at secondary lead smelters. The amount of antimony used by battery manufacturers was substantially lower than it was 10 years earlier because of changing materials requirements for batteries. Industry stocks declined by 24% owing to rising antimony prices as consumers found the metal harder to obtain (table 1).

About 40% of the primary antimony used in the United States during 2005 went into flame retardants; most of the rest was used by the ceramic, chemical, glass, and transportation industries. Secondary antimony, which was derived almost entirely from recycled lead-acid batteries and contained in antimonial lead, was used in the manufacture of new batteries. In 2005, the average price of antimony was 160.5 cents per pound and was 23% higher than that of 2004.

Antimony was mined as a principal product or was a byproduct of the smelting of base-metal ores in 12 countries. World mine production rose by 8%. Nearly all the world's primary antimony was mined in China (86%), South Africa (4%), Bolivia (2%), Russia (2%), Tajikistan (1%), and Australia (1%) (table 9).

Production

Mine Production.—There was no domestic mine production in 2004. The Nation's last domestic byproduct antimony producer, Sunshine Mining Co. in Idaho, closed its mine in early 2001.

Smelter.—The United States had only one antimony smelter, U.S. Antimony Corp. (USAC) based in Thompson Falls, MT. USAC produced antimony metal for bearings, lead alloys, and ordnance; antimony oxide as a raw material for flame retardants; and sodium antimonite for glass and other applications. USAC also recycled antimony-containing products that would otherwise be taken to landfill sites.

A major antimony smelter, Great Lakes Chemical Corp. in Indianapolis, IN, merged with Crompton Corp. of Middlebury, CT, to form a new business entity, Chemtura Corp. based in Middlebury. Although Great Lakes Chemical Corp. had been based in Lafayette, IN, it did not have a domestic antimony smelter, but operated an antimony smelter in Reynosa, Mexico, as part of GLCCLaurel LLC (a 50% joint ownership stake with Occidental Chemical Corp.). The all-stock merger creating Chemtura represented the fourth largest publicity traded American specialty chemicals producer and the world's largest plastics additives company (Chemtura Corp., 2005).

Consumption

Of the 137 companies to which a U.S. Geological Survey antimony consumption survey was sent, 66 firms responded. Consumption data were estimated for the remaining 71 firms. Reported and estimated U.S. consumption was only about one-third of net imports.

In 2005, consumption (reported and estimated) of primary antimony declined by 22% from that of 2004 (table 2). Consumption for most categories declined moderately except for flame retardants, which declined by 39% from that of 2004 (table 3). Industry sources attributed the decline in use of flame retardants to increasing competition from ammonium polyphosphate and the movement offshore of some plants that consume the flame retardants.

Lead-antimony alloys were used in ammunition, antifriction bearings, automotive batteries, cable sheaths, corrosion-resistant pumps and pipes, roof sheet solder and tank lining. Antimony trioxide, often dissolved in an organic solvent, was used to enhance the flame-retardant properties of rubber and textiles, plastics, and other combustibles. Antimony was also used as a decolorizing and refining agent in the manufacture of some forms of glass, such as optical glass.

Prices

In 2005, antimony prices continued the strong upward trend that began in 2002. Antimony prices started the year in the range of $1.33 to $1.37 per pound and finished the first quarter in the range of $1.45 to $1.50 per pound. Prices remained fairly steady in the second quarter. By the end of the third quarter, prices had risen to a range of $1.83 to $1.89 per pound. Prices in the fourth quarter remained rather steady and finished the year at $1.82 to $1.89 per pound. The average antimony price for the year increased by 23% compared with that of 2004. The price increase was attributed to increased world demand that outpaced a modest increase in world mine output.

Trade

U.S. imports of antimony in 2005 were, as has been the case in the past, much larger than exports—about 14-fold larger (tables 5-8). Imports of antimony declined by 13% from the level of 2004, with antimony ore and concentrate experiencing the largest relative decrease. China was the leading supplier to the United States of antimony ore, antimony concentrate,

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and antimony metal, while China and Mexico were the leading suppliers of antimony oxide.

World Review

Australia.—A.G.D. Mining Ltd. of Melbourne announced its intention to proceed with its antimony and gold project in Augusta. A.G.D. had launched a $2.4 million share issue in August 2004 to provide initial equity funding. A.G.D.'s major shareholder, Cambrian Mining plc of Melbourne will contribute $7.1 million to the mine development and process plant construction. The project was expected to produce an average of 918 kilograms per year (29,500 troy ounces per year) of gold and 3,300 metric tons per year (t/yr) of antimony-in-concentrate over an initial mine life of 3 years. Production was expected to begin early 2006 (Metal-Pages, 2005a§[1]).

Northwest Resources Ltd. of Darling Point, New South Wales announced that it expected to drill extensively in 2006 to develop its existing antimony and gold prospects. The prospects are located in the Nullagine goldfield area in the central Pilbara region of Western Australia. The company planned to concentrate on the Blue Spec Shear project area, which reportedly had a very high-grade gold and antimony mineralization. The separation of antimony and gold during processing was not expected to present significant metallurgical problems (Metal-Pages, 2005b§).

China.—China's antimony resources were mainly distributed in Gansu, Guangxi, Guizhou, Hunan, Jianxgi, and Yunnan Provinces. Hunan has taken the place of Guangxi as the leading antimony ore producing area in China. Many significant antimony mines have exhausted more than 80% of their reserves, and the quality and the quantity of the ores were declining. In 2005, the Ministry of Land and Resources released a list of the 291 operations it certified as miners of antimony, rare earths, and tin (Beijng Antaike Information Development Co., Ltd., 2006).

In 2005, antimony smelters faced tighter supplies of raw materials, and many of them depended increasingly on concentrate inventories. Hunan, Guangxi, and Yunnan Provinces, respectively, contributed 59%, 20%, and 10% to the national output of refined antimony. Among antimony refiners reporting an increase in antimony production in 2005 were Dushan County Dongfeng Group Co., Ltd.; Hechi City South Nonferrous Metals Co., Ltd.; Hsikwangshan Twinkling Star Antimony Co., Ltd.; and Yiyang City Hongda Antimony Co., Ltd. Data from the General Administration of Customs (GAS) showed that China imported 21,900 metric tons (t) of antimony concentrates in 2005 compared with 18,000 t in 2004 (Beijng Antaike Information Development Co., Ltd., 2006). In addition the GAS announced that exports of antimony surged during 2005. China exported 29,800 t of antimony in 2005, an increase of 39% compared with that in 2004 (Metal-Pages, 2006a§).

The Ministry of Commerce for China issued a list of 31 state-owned trading companies authorized to export antimony during 2006. Included were Chengyuan Smelting Co., Ltd; China Minmetals Nonferrous Metals Co., Ltd.; Dongguan Jiefu Co., Ltd.; Hechi Wuji Co., Ltd.; Liuzhou China Tin Group Co., Ltd.; Shanxing Antimony Corp., Ltd.; and Yunnan United Antimony Co., Ltd. (Metal-Pages, 2006b§).

There were fewer than 60 antimony smelters maintaining normal production, and only 3 of those (Hsikwangshan Twinkling Star; Hunan Chenzhou Mining Co., Ltd; and Liuzhou China Tin) had a capacity of more than 5,000 t/yr. There were also three antimony oxide producers with production capacity of more than 5,000 t/yr—Guangxi Huati Chemical Co., Ltd., Hsikwangshan Twinkling Star, and Yunnan Muli Antimony Co., Ltd. Of China's antimony consumption, 50% goes to the flame-retardant industry. China consumed an estimated 30,000 t of antimony in 2005 (Beijng Antaike Information Development Co., Ltd., 2006).

After a 2-month shutdown, production returned to the full capacity of 24,000 t/yr at Hsikwangshan Twinkling Star's Lengshuijiang City facilities in central Hunan Province. A power reduction at the company's North Mine and smelter had forced closure of these facilities and reduced company output by one-half during the 2-month shutdown. Production had continued at the South smelter during the shutdown (Metal Bulletin Daily, 2005).

Mexico—USAC announced that Antimonio de Mexico, S.A. de C.V. (50% owned by USAC) began exploration of an antimony and silver property in Mexico that is located in a major silver belt. The Mexican Government previously had reported resources of 1 million metric tons at a grade of 1.8% antimony and 252 grams per metric ton (7.4 troy ounces per metric ton) silver based on exploration work that was carried out in 1969. Metallurgical testing at that time was unable to separate the antimony from the silver. Antimonio has completed preliminary metallurgical testing of the rock and has been able to make an antimony product and a silver product. Should the exploration work confirm substantial reserves, Antimonio intended to build a milling facility close to the open pit mine. The antimony output would be shipped to USAC in Thompson Falls for processing and marketing (Metal-Pages, 2005c§).

Outlook

The use of antimony as an ingredient in flame retardants is expected to remain its principal use. This is expected to be true for global as well as U.S. markets.

Antimony recovered from old scrap has long been an important part of the total antimony supply, but the recovery decline during the past 25 years as a significant source is expected to continue. Following the advent in the 1970s of low-maintenance and maintenance-free automotive batteries, the antimony content of a typical automotive lead-acid battery in 2005 had fallen to about 0.6% or lower. Industry sources believed the antimony level in lead-acid batteries would reach zero by 2020.

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TABLE 1
SALIENT ANTIMONY STATISTICS[1]

(Metric tons of antimony content unless otherwise specified)

		2001	2002	2003	2004	2005
United States:						
Production:						
Primary:						
Mine, recoverable antimony		--	--	--	--	--
Smelter		9,080	W	W	W	W
Secondary		5,380	5,350	5,600	3,650 r	3,670
Exports:						
Metal, alloys, waste and scrap	gross weight	1,730	992	771	566	740
Antimony oxide[2]		5,880	3,260	2,910	3,240	1,400
Imports for consumption		37,900	28,500	26,700	33,500	29,200
Reported industrial consumption, primary antimony		13,100	11,500	9,230	11,400 r	8,910
Stocks, primary antimony, all classes, December 31		4,990	5,060	6,320	2,830 r	2,130
Price, average[3]	cents per pound	64.7	88.4	107.5	130.3	160.5
World, mine production		157,000	114,000 r	115,000 r	129,000 r	139,000 e

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Data are rounded to no more than three significant digits, except prices.

[2]Antimony content is calculated by the U.S. Geological Survey.

[3]New York dealer price for 99.5% to 99.6% metal, cost, insurance, freight U.S. ports.

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TABLE 2
REPORTED INDUSTRIAL CONSUMPTION OF
PRIMARY ANTIMONY IN THE UNITED STATES[1]

(Metric tons of antimony content)

Year	Class of material consumed			
	Metal	Oxide	Other[2]	Total
2004	1,750 r	9,570 r	84	11,400 r
2005	1,530	7,290	89	8,910

rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes residues and sulfide.

TABLE 3
REPORTED INDUSTRIAL CONSUMPTION OF PRIMARY ANTIMONY IN THE
UNITED STATES, BY PRODUCT[1]

(Metric tons of antimony content)

Product	2004	2005
Metal products:		
Antimonial lead	1,200	W
Bearing metal and bearings	51 r	33
Solder	85	81
Other[2]	1,680	2,830
Total	3,020 r	2,940
Nonmetal products:		
Ammunition primers	W	W
Ceramics and glass	535 r	421
Pigments	536 r	535
Plastics	W	W
Other[3]	1,410	1,410
Total	2,480 r	2,360
Flame retardants:		
Adhesives	676	W
Plastics	4,680	2,650
Rubber	119	115
Textiles	189	184
Other[4]	63	652
Total	5,910 r	3,600
Grand total	11,400 r	8,910

rRevised. W Withheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes ammunition, cable covering, castings, sheet and pipe, and type metal.

[3]Includes fireworks and rubber products.

[4]Includes paper and pigments.

NOTE: Secondary antimonial lead production was 3,650 metric tons (t) in 2004 and an estimated 3,670 t in 2005.

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TABLE 4
INDUSTRY STOCKS OF PRIMARY ANTIMONY
IN THE UNITED STATES, DECEMBER 31[1]

(Metric tons of antimony content)

Type of material	2004	2005
Metal	483 r	425
Oxide	2,330 r	1,690
Other[2]	16	17
Total	2,830 r	2,130

rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes ore and concentrate, residues, and sulfide.

TABLE 5
U.S. EXPORTS OF ANTIMONY METAL, ALLOYS, AND WASTE AND SCRAP,
BY COUNTRY[1]

	2004		2005	
Country	Gross weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Value (thousands)
Canada	370	$1,180	390	$1,290
Costa Rica	3	11	--	--
El Salvador	22	66	--	--
Mexico	97	365	281	1,270
Netherlands	41	143	(2)	36
Sweden	9	144	14	236
Switzerland	2	27	5	107
Other	24	345	50	313
Total	566	2,280	740	3,250

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

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TABLE 6
U.S. EXPORTS OF ANTIMONY OXIDE, BY COUNTRY[1]

Country	2004			2005		
	Gross weight (metric tons)	Antimony content[2] (metric tons)	Value (thousands)	Gross weight (metric tons)	Antimony content[2] (metric tons)	Value (thousands)
Argentina	153	127	$635	--	--	--
Australia	15	12	45	118	98	$322
Belgium	115	95	656	69	57	198
Brazil	67	56	237	11	9	53
Canada	1,520	1,260	4,400	287	238	982
Chile	12	10	41	34	28	85
China	49	41	136	65	54	280
Colombia	65	54	208	20	17	27
France	96	80	755	36	30	129
Germany	49	41	180	2	2	5
Japan	282	234	926	76	63	317
Korea, Republic of	211	175	690	96	80	277
Mexico	738	613	2,060	524	435	1,670
New Zealand	32	27	138	10	8	48
Pakistan	20	17	111	12	10	71
Singapore	14	12	95	39	32	242
South Africa	41	34	110	--	--	--
Taiwan	26	22	186	41	34	293
Thailand	78	65	230	21	17	71
Turkey	63	52	278	1	1	8
United Kingdom	174	144	749	100	83	402
Other	79	64	306	122	101	374
Total	3,910	3,240	13,200	1,680	1,400	5,860

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Antimony content is calculated by the U.S. Geological Survey.

Source: U.S. Census Bureau.

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TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF ANTIMONY, BY CLASS AND COUNTRY[1]

Country	2004			2005		
	Gross weight (metric tons)	Antimony content[2] (metric tons)	Value (thousands)	Gross weight (metric tons)	Antimony content[2] (metric tons)	Value (thousands)
Antimony ore and concentrate:						
China	1,450	1,380	$3,860	150	147	$443
Hong Kong	--	--	--	40	40	127
Japan	(3)	(3)	4	(3)	--	4
Peru	--	--	--	18	17	48
Russia	195	194	542	--	--	--
Saudi Arabia	100	100	295	--	--	--
Vietnam	80	80	202	--	--	--
Total	1,820	1,750	4,900	207	204	622
Antimony oxide:						
Australia	--	--	--	(3)	(3)	5
Belgium	2,110	1,750	4,670	1,870	1,550	5,660
Brazil	19	16	38	--	--	--
Canada	--	--	--	1	1	8
China	12,900	10,700	30,700	11,500	9,510	33,600
France	1	1	8	3	3	24
Germany	10	8	141	5	4	80
Hong Kong	520	432	1,370	176	146	522
Iceland	--	--	--	22	18	9
Japan	171	142	765	239	199	2,580
Kyrgystan	126	105	266	--	--	--
Liechtenstein	(3)	(3)	4	--	--	--
Mexico	11,600	9,590	28,500	12,000	9,930	34,100
South Africa	790	656	628	--	--	--
Switzerland	38	32	114	36	30	116
Taiwan	3	2	9	--	--	--
United Kingdom	(3)	(3)	6	--	--	--
Vietnam	20	17	49	1,540	1,280	4,950
Total	28,300	23,500	67,200	27,300	22,700	81,600

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Antimony ore and concentrate content reported by the U.S. Census Bureau. Antimony oxide content is calculated by the U.S. Geological Survey.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF ANTIMONY METAL, BY COUNTRY[1]

	2004		2005	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Belgium	168	$386	701	$1,850
Bolivia	--	--	20	$50
Canada	100	826	108	1,130
Chile	20	45	20	50
China	5,820	14,700	3,870	13,500
France	11	29	--	--
Germany	(2)	104	(2)	104
Hong Kong	--	--	135	446
Japan	1	60	1	99
Mexico	785	707	900	844
Netherlands	19	47	--	--
Peru	501	875	461	1,590
Russia	105	258	21	60
South Africa	649	756	--	--
Taiwan	20	56	19	73
United Kingdom	46	102	--	--
Vietnam	20	53	110	569
Other	12	5	5	7
Total	8,270	19,100	6,370	20,400

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 9

ANTIMONY: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Australia[4]	1,380	1,200 [e]	1,300 [e]	1,800	1,900
Bolivia	2,264	2,336	2,911	3,118 [r]	3,100
Canada[5]	278 [r]	173 [r]	153 [r]	112 [r]	120
China[e]	140,000	100,000	100,000	110,000 [r]	120,000
Guatemala	--	--	20	2,686	2,700
Kyrgyzstan[e]	150	150	40	20	10
Peru, refined	274	356	356 [e]	356 [e]	360
Russia, recoverable[e]	4,500	1,000 [r]	2,000 [r]	3,000 [r]	3,000
South Africa[5]	4,927	5,746	5,291 [r]	4,967 [r]	5,000
Tajikistan[e]	2,500	3,000	1,800	2,000	2,000
Thailand, content of ore and concentrate	18	1	38	52 [r]	50
Turkey[e]	330	250	650	900 [r]	900
Total	157,000	114,000 [r]	115,000 [r]	129,000 [r]	139,000

[e]Estimated. [r]Revised. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Antimony content of ore unless otherwise indicated. Table includes data available through May 27, 2006.

[3]In addition to the countries listed, antimony may have been produced in Iran, but information is inadequate to estimate output.

[4]Antimony content of antimony ore and concentrate, lead concentrates, and lead-zinc concentrates.

[5]Antimony content of concentrate.

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ARSENIC

By William E. Brooks

Domestic tables were prepared by Elsie D. Isaac, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

There has been no domestic production of arsenic trioxide (As_2O_3) or arsenic metal since 1985, and the United States was import dependent for all of its supply. In 2005, domestic imports of As_2O_3 increased to 8,330 metric tons (t), an approximate increase of 35% compared with the 6,150 t of As_2O_3 imported in 2004. Owing to a voluntary phaseout of arsenical wood preservatives for nonindustrial uses at yearend 2003, this was still about 60% less than the amount of As_2O_3 imported in 2003. The United States remained the world's leading consumer of arsenic, as As_2O_3, primarily as a component of chromated copper arsenate (CCA), a pesticide-preservative for pressure-treated wood products in commercial applications. Arsenic metal and As_2O_3 were also used for agricultural chemicals, electronics, and nonferrous alloys. China was the source of 51% of the As_2O_3 imported into the United States, Morocco was the source of 30%, and Hong Kong, 10%. Imports of arsenic metal have generally declined since 2001, and in 2005, the United States imported 812 t of arsenic metal, down from 872 t in 2004. China was the leading source, accounting for 718 t, down from 730 t in 2004.

Legislation and Government Programs

In response to health concerns over arsenic contamination in public water systems, the U.S. Environmental Protection Agency (EPA) has set the arsenic standard for drinking water at 10 micrograms per liter (µg/l). Municipal water suppliers were to comply with this standard by January 2006 (U.S. Environmental Protection Agency, 2006§[1]). Arsenic is a common, naturally occurring element that may be a drinking water contaminant. Rural communities have complained that they cannot afford to purchase the systems needed to reduce the arsenic content of water to 10 µg/l. Especially in the southwestern United States, such systems may need to lower the pH of the water by using carbon dioxide or sulfuric acid. Therefore, the EPA has proposed to make it permissible for water systems serving 10,000 or fewer residents to have up to 30 µg/l arsenic in their water (Eilperin, 2006a). In 2004, the U.S. Food and Drug Administration proposed a rule that would insure that the amount of arsenic in bottled water would be comparable with the quality of public drinking water (U.S. Food and Drug Administration, 2004).

Under current U.S. law, aging coal-fired powerplants, chemical plants, and incinerators that emit 10 metric tons per year (t/yr) or more of a single toxin or 25 t/yr or more of a combination of toxins, including arsenic, mercury, and lead, must install maximum achievable control technology to cut the emissions by 95%. A draft proposal by the EPA would lift that requirement from plants that have reduced emissions to below 25 t/yr. Critics argued that if the draft rule were to be implemented, polluters could emit many more tons of arsenic, mercury, and lead by running pollution controls at half-speed (Eilperin, 2006b).

At yearend 2003, domestic manufacturers of arsenic-containing wood preservatives began a voluntary cutback in use of such preservatives after consulting with the EPA. The voluntary phaseout of CCA applied to wood used for boardwalks, decks, fencing, gazebos, picnic tables, and play structures. Wood treated prior to December 31, 2003, could still be used, and glue-laminated beams, marine timbers, plywood flooring and roofing, and utility poles could still be treated with CCA (American Wood Preservers Institute, 2003§).

Environmental Issues

Following the International Conference on Arsenic in 1995 in Calcutta, India, sponsored by the School of Environmental Studies, Jadavpur University, the problem of arsenic in ground water became more widely known by scientists outside of India and an increasing health concern. A study in one district in Bangladesh, for example, found that more than 90% of the water wells had arsenic levels higher than 50 µg/l (Meharg, 2005, p. 16). In Bangladesh, the problem is exacerbated because rice that is grown in ground-water-flooded fields bioaccumulates arsenic, and then the rice may be cooked in arsenic-laden water, which drives the arsenic load even higher (Mehard, 2005, p. 18). In rural and urban water supplies in Peru, arsenic contamination is blamed on mining waste and pesticide use (Luna, 2005).

Arsenic is one of several hazardous elements contained in many electronic products, specifically in the circuit boards of computers, relays, and switches (Ohio Department of Natural Resources, 2005§). In celebration of Earth Day, some organizations posted the locations of dropsites for safe disposal and recycling, or "e-cycling," of computer electronics which may contain arsenic or other hazardous elements (Washington Post, The, 2006). Of global concern was that these electronics, which include used computers and televisions, were being exported and became part of uncontrolled hazardous waste in China or Nigeria (Grossman, 2005).

In the aftermath of Hurricane Katrina, arsenic was one of several contaminants deposited in sludge across New Orleans, LA. Maps have been produced that show several high arsenic areas in the city, and removal of the sludge has been discussed (Hsu and Eilperin, 2006).

Consumption

In 2005, the United States was again the world's leading consumer of arsenic, mainly for CCA. In response to the voluntary ban on CCA at yearend 2003, the global arsenic market declined sharply. Apparent domestic demand was 8,800 t in 2005, up by almost 30% from 6,800 t in 2004, yet far less

[1]References that include a section mark (§) are found in the Internet References Cited section.

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than the 21,600 t of arsenic in 2003. The estimated value of arsenic compounds and metal consumed domestically in 2005 was approximately $7 million.

In 2005, about 65% of the arsenic, as As_2O_3, was used in the wood preservative industry for nondomestic use, down from about 90% prior to 2004; the remainder was used in agricultural chemicals, either directly or after conversion to arsenic acid, such as desiccants, glass manufacturing applications., herbicides, and insecticides. Major U.S. producers of CCA included Arch Wood Protection, Inc., Smyrna, GA; Chemical Specialties, Inc., Charlotte, NC; and Osmose Wood Preserving, Inc., Buffalo, NY. Arsenic acid is also used as a bubble dispersant or decoloring agent in glassmaking.

Arsenic metal, used as a hardener, is alloyed with lead and antimony for ammunition, solders, and other applications. Arsenic is one of several metals used as an antifriction additive to metals (babbitts) used for bearings. Grids and posts in lead-acid storage batteries are strengthened by the addition of arsenic metal. Arsenic is used in lead shot, and in addition to lead and antimony, minor amounts of arsenic are used in clip-on wheel weights (Los Angeles Silhouette Club, 2006§).

Gallium arsenide (GaAs) semiconductors are used in lasers, light emitting diodes, and solar cells. Gallium-arsenide and indium-arsenide semiconductors for use in computers and electronic devices require high-purity (99.9999%-pure) arsenic metal. Arsenic is also an important component of GaAs wafers for electronics applications. Indium-gallium-arsenide is used for Short Wave Infrared technology (Metal-Pages, 2005§). Arsenic may be used for germanium-arsenide-selenide or GaAs specialty optical materials (Harrick Optical Materials, 2006§). Domestic demand for gallium and arsenic in wafer production declined significantly in 2002 owing to the buildup of the domestic GaAs inventory, closure of several domestic plants, and increased wafer manufacturing in China. Based on reported consumption of gallium, domestic consumption of arsenic metal in GaAs semiconductors declined to approximately 15 t in 2005 from a peak of about 40 t in 2000 (D.A. Kramer, gallium commodity specialist, U.S. Geological Survey, written commun., April 28, 2006).

Imports into the United States of As_2O_3 from China rose to 5,620 t in 2005 and were significantly higher than the 3,040 t imported in 2004. However, the total amounts of As_2O_3 imported in 2005 and 2004 were dramatically lower than the 20,600 t of As_2O_3 imported in 2003.

World Review

Reduction of As_2O_3 to arsenic metal accounted for all world output of commercial-grade (99%-pure) arsenic metal (Roskill Information Services Ltd., 1992, p. 2). China continued to be the leading world producer of commercial-grade arsenic metal, and the U.S. imported 700 t from China, followed by 90 t from Japan, in 2005.

In 2005, as in previous years, As_2O_3 was obtained from the treatment of nonferrous ores, or concentrates in 14 countries. In China, arsenic is also obtained as a byproduct of gold mining. Orpiment and realgar, the more common ore minerals of arsenic, are routinely stockpiled near the Qiaoqiaoshang gold mine, northern Sichuan Province, for transport and processing in Guizhou Province (Peters and others, 2002, p. 182).

Arsenic-containing residues and smelter dusts recovered from nonferrous plants in several countries were not processed to commercial grade As_2O_3 in 2005 and may have been stockpiled for future treatment. As in previous years, China remained the world's leading producer of As_2O_3, followed by Chile and Peru. Country data are estimated and subject to revision because As_2O_3 production may not be accurately reported.

Outlook

The use of alternative wood preservatives or wood alternatives, such as concrete, plastic, or wood composites, will continue to increase because of environmental and health concerns over the use of CCA as a wood preservative. The voluntary decision by the wood preservative industry to eliminate CCA as a wood preservative for specified wood products at yearend 2003 has led to a decline in U.S. demand and has affected As_2O_3 production in China. CCA-treated wood, however, will continue to be used for specific industrial applications such as marine timber, plywood roofing, and utility poles. High-purity arsenic will continue to be used by the electronics industry for GaAs semiconductors for automotive uses, military and space applications, solar cells, and telecommunications. World sources of arsenic, as As_2O_3 and arsenic metal available from nonferrous metal processing in 14 countries, are sufficient to meet projected needs.

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TABLE 1
ARSENIC SUPPLY-DEMAND RELATIONS[1]

(Metric tons of arsenic content)

	2001	2002	2003	2004	2005
U.S. supply:					
Imports:					
Metal	1,030	879	990	872	812
Compounds	23,900	18,800	20,800	6,150	8,330
Total	25,000	19,700	21,700	7,020	9,150
Distribution of U.S. supply:					
Exports[2]	57	100	173	220	327
Apparent demand	24,900	19,600	21,600	6,800	8,820
Estimated U.S. use:					
Agricultural chemicals	1,000	750	860	850	1,000
Glass	750	700	660	650	700
Wood preservatives	21,900	17,300	19,200	4,450	5,760
Nonferrous alloys and electronics	1,000	650	660	650	1,100
Other	250	200	200	200	250
Total	24,900	19,600	21,600	6,800	8,810

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Metal only.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF ARSENIC PRODUCTS[1]

	2004		2005	
Class and country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Arsenic trioxide:				
Belgium	292	$202	307	$209
Bolivia	180	101	120	64
Chile	104	44	78	33
China	3,040	1,340	5,620	2,680
Germany	54	107	(2)	4
Hong Kong	464	230	1,140	606
Japan	--	--	--	--
Mexico	927	558	344	234
Morocco	2,950	1,450	3,350	1,450
Spain	91	43	(2)	3
Total	8,090	4,080	11,000	5,280

See footnotes at end of table.

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TABLE 2—Continued
U.S. IMPORTS FOR CONSUMPTION OF ARSENIC PRODUCTS[1]

Class and country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Arsenic acid:				
China	20	$20	--	--
France	2	12	9	$50
Total	22	32	9	50
Arsenic sulfide:				
Canada	(3)	(3)	--	--
Russia	(2)	2	--	--
Total	(2)	2	--	--
Arsenic metal:				
China	730	1,300	718	1,790
Germany	6	847	5	758
Hong Kong	20	20	--	--
Japan	116	862	90	860
United Kingdom	(2)	6	--	--
Total	872	3,030	812	3,410

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Less than ½ unit.
[3]Revised to zero.

Source: U.S. Census Bureau.

TABLE 3
ARSENIC TRIOXIDE: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2, 3]

(Metric tons)

Country[4]	2001	2002	2003	2004	2005
Belgium	1,000	1,000	1,000	1,000	1,000
Bolivia	846 [5]	237 [5]	276 [5]	168 [r, 5]	150
Canada	250	250	250	250	250
Chile	11,500 [r]	11,400 [r]	11,600 [r]	11,600 [r]	11,500
China	39,500	40,000	40,000	30,000	30,000
France	1,000	1,000	1,000	1,000	1,000
Germany	200	200	200	200	200
Iran	400	400	275 [r, 5]	89 [r, 5]	100
Japan	40	40	40	40	40
Kazakhstan	1,500	1,500	1,500	1,500	1,500
Mexico	2,381 [5]	1,946 [5]	1,729 [r, 5]	1,829 [r, 5]	1,650
Peru[6]	2,800 [5]	2,970 [5]	3,000 [5]	3,500	3,600
Portugal	50	50	50	50	50
Russia	1,500	1,500	1,500	1,500	1,500
Total	63,000 [r]	62,500 [r]	62,400 [r]	52,700 [r]	52,500

[r]Revised.
[1]Including calculated arsenic trioxide equivalent of output of elemental arsenic compounds other than arsenic trioxide where inclusion of such materials would not duplicate reported arsenic trioxide production.
[2]World totals and estimated data have been rounded to no more than three significant digits; may not add to totals shown.
[3]Table includes data available through April 1, 2006.
[4]Austria, Hungary, the Republic of Korea, Serbia and Montenegro, South Africa, Spain, Ukraine, the United Kingdom, and Zimbabwe have produced arsenic and/or arsenic compounds in previous years, but information is inadequate to make estimates of output levels, if any.
[5]Reported figure.
[6]Output of Empresa Minera del Centro del Perú (Centromín Perú) as reported by the Ministerio de Energía y Minas.

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ASBESTOS

By Robert L. Virta

Domestic survey data and tables were prepared by Subina W. Pandey, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Asbestos has not been mined in the United States since 2002 and imports, mostly from Canada, satisfied domestic manufacturing needs. U.S. apparent consumption declined to 2,530 metric tons (t) in 2005. World production was 2.40 million metric tons (Mt), an increase from 2.36 Mt in 2004.

Legislation and Government Programs

The Agency for Toxic Substances and Disease Registry (ATSDR) and the National Institute for Occupational Safety and Health (NIOSH) of the U.S. Department of Health and Human Services and the U.S. Environmental Protection Agency (EPA) continued with their exposure and health studies of residents and former vermiculite miners and millers in Libby, MT. The EPA continued its cleanup of asbestos-contaminated properties in Libby and conducted studies of asbestos exposure in El Dorado County, CA. The ATSDR continued to review health statistics for communities near vermiculite exfoliation plants located throughout the United States. The NIOSH continued its study of workers formerly employed at a South Carolina textile plant and to develop a model to better predict risk to humans from fiber exposure for which dose response data are not available (U.S. Environmental Protection Agency, 2005§[1]).

The Mine Safety and Health Administration continued to evaluate its proposed reduction of the 8-hour time-weighted average permissible exposure level to 0.1 fiber per cubic centimeter (f/cm^3) from 2 f/cm^3 for asbestos. A decision was scheduled for July 2006 (U.S. Department of Labor, 2005§).

Consumption

U.S. consumption of asbestos was 2,530 t in 2005, a decrease from 3,450 t in 2004 (table 1). Roofing products accounted for 55% of U.S. consumption; coating and compounds, 26%; other uses, 19%; and electrical insulation, less than 1%. Chrysotile was the only type of asbestos used in the United States. About 73% of the chrysotile used in the United States in 2005 was grade 7; the rest was grades 5, 4, and 3, in descending order of percentage (table 2).

Prices

The average free alongside ship (f.a.s.) unit value of asbestos fiber exports and reexports was $263 per metric ton in 2005, an increase from $211 per ton in 2004. The average U.S. customs unit value for all grades of imported asbestos increased to $561 per ton in 2005 from $234 per ton in 2004. The average value of imported crude chrysotile increased to $188 per ton in 2005 from $46 per ton in 2004 because of unusually low-value transshipments through Germany in 2004. The average unit value for imports of spinning-grade chrysotile from all sources was $150 per ton in 2005, unchanged from 2004. The unit value of other grades of chrysotile from all sources was $600 per ton, an increase from $318 per ton in 2004. This resulted because larger quantities of higher valued chrysotile were imported from Canada and transshipped through South Africa in 2005 than in 2004 (table 6). Average prices for chrysotile imported from Canada, which composed 88% of U.S. asbestos imports, are given in table 3.

Foreign Trade

Imports of asbestos products and products manufactured using asbestos substitutes are reported under the same Harmonized Tariff Schedule of the United States (HTS) codes (U.S. Census Bureau, 2001§). With the decline in use of asbestos products in the United States and bans on the manufacture of asbestos products in many other countries, it is likely that products manufactured using asbestos substitutes account for a significant portion of the product imports under some HTS categories. This fact must be taken into consideration when evaluating the trade data that follow.

The f.a.s. value of exported asbestos fibers increased to $398,000 in 2005 from $333,000 in 2004. Mexico was the leading importer of asbestos fiber from the United States. Canada was the leading importer of U.S. products manufactured using asbestos or asbestos substitutes, followed by Mexico, Japan, Thailand, Germany, the Republic of Korea, the United Kingdom, Saudi Arabia, Australia, and Brazil. These 10 countries accounted for 79% of the value of manufactured products reexported from the United States in 2005 (table 4).

In 2005, approximately 1,510 t of asbestos was exported (U.S. International Trade Commission, 2005§). The exports included asbestos crude, fiber, refuse, sand, and stucco. There has been no U.S. production since 2002, so exports were either from stockpiles or reexports of imported fiber (table 5).

Brake linings, clutch linings, disk pads, mounted brake linings manufactured using asbestos, other mineral substances, or cellulose accounted for 86% of the value of manufactured products that were exported or reexported in 2005 (table 5). Products in these categories composed more than 79% of the value of exports to each of the countries specified in table 4.

In 2005, Canada supplied 88% of the asbestos imported by the United States. Asbestos also was imported from Zimbabwe (table 6). Only chrysotile was imported into the United States in

[1]References that include a section mark (§) are found in the Internet References Cited section.

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2005. Based on the import source, asbestos listed under "Other, unspecified asbestos type" in table 6 probably was chrysotile.

The United States also imported $579 million worth of products with a basis of asbestos, asbestos and magnesium carbonate, cellulose fiber, or other mineral substances (U.S. International Trade Commission, 2005§) (table 7).

World Review

World production of asbestos was estimated to be 2.40 Mt in 2005, an increase from 2.36 Mt in 2004. Russia continued to be the leading producer of asbestos, followed by China, Kazakhstan, Canada, Brazil, and Zimbabwe. These countries accounted for 96% of the world production (table 8).

Outlook

Domestic use of asbestos probably will continue its downward trend in the United States because of liability issues. World production has remained relatively unchanged since 2002 and probably will remain between 2.3 and 2.4 Mt for the next couple of years.

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TABLE 1
SALIENT ASBESTOS STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Production, sales	metric tons	5,260	2,720	--	--	--
Exports and reexports:[2]						
Unmanufactured, value	thousands	$4,890	$2,020	$920	$333	$398
Asbestos products, value	do.	$298,000	$203,000	$290,000	$341,000	$374,000
Imports for consumption, unmanufactured:						
Quantity	metric tons	13,100	6,850	4,650	3,450	2,530
Value[3]	thousands	$2,640	$1,770	$5,840	$806	$1,420
Consumption, apparent[4]	metric tons	13,100	6,850	4,650	3,450	2,530
World, production	do.	2,060,000 r	2,320,000 r	2,360,000 r	2,360,000 r	2,400,000 e

eEstimated. rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits.

[2]Free alongside ship value; includes exports of crudes, fibers, stucco, sand, and refuse. May also include nonasbestos materials.

[3]U.S. customs declared value.

[4]Production plus imports minus producer exports of asbestos fiber plus adjustments in Government and industry stocks.

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TABLE 2
U.S. ASBESTOS CONSUMPTION BY END USE, GRADE, AND TYPE[1, 2]

(Metric tons)

	Chrysotile						
End use	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Unspecified grade	Total
2004	--	29	240	--	1,990	1,190	3,450
2005:							
Coatings and compounds	--	--	293	--	367	--	660
Electrical insulation	11	--	--	--	--	--	11
Roofing products	--	--	--	--	1,380	--	1,380
Other	10	84	--	--	87	298	479
Total	21	84	293	--	1,840	298	2,530

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Estimated distribution based upon data provided by the Chrysotile Institute, Montreal, Quebec, Canada.

TABLE 3
CUSTOMS UNIT VALUE OF IMPORTED ASBESTOS

(Dollars per metric ton)

	2004	2005
Canada, chrysotile:		
Crude	193	188
Spinning	157	170
Other	213	334

Source: U.S. Census Bureau.

TABLE 4
VALUE OF U.S. EXPORTS AND REEXPORTS OF ASBESTOS FIBERS AND PRODUCTS[1, 2]

(Thousand dollars)

	2004			2005		
Country	Unmanufactured fiber[3]	Manufactured products[4]	Total	Unmanufactured fiber[3]	Manufactured products[4]	Total
Australia	--	3,470	3,470	--	4,060	4,060
Brazil	--	4,760	4,670	--	3,800	3,800
Canada	--	169,000	169,000	--	177,000	177,000
Germany	--	9,180	9,180	--	10,100	10,100
Japan	--	15,100	15,100	--	15,500	15,500
Korea, Republic of	--	11,500	11,500	--	9,450	9,450
Kuwait	--	999	999	--	1,150	1,150
Mexico	317	44,200	44,500	347	46,300	46,600
Saudi Arabia	--	5,040	5,040	--	7,160	7,160
Thailand	--	13,000	13,000	--	12,000	12,000
Turkey	--	129	129	--	140	140
United Kingdom	--	7,360	7,360	--	8,780	8,780
Venezuela	--	1,410	1,410	--	1,590	1,590
Other	16	56,300	56,300	51	76,900	77,000
Total	333	341,000	342,000	398	374,000	375,000

See footnotes at end of table.

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TABLE 4—Continued

VALUE OF U.S. EXPORTS AND REEXPORTS OF ASBESTOS FIBERS AND PRODUCTS[1, 2]

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship value.

[3]Includes exports of crudes, fibers, stucco, sand, and refuse. May also include nonasbestos materials.

[4]Includes products manufactured using asbestos, cellulose fiber, and other asbestos substitutes.

Source: U.S. Census Bureau.

TABLE 5

U.S. EXPORTS AND REEXPORTS OF ASBESTOS AND ASBESTOS PRODUCTS[1]

	2004		2005	
	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Unmanufactured, asbestos[3]	1,580	$333,000	1,510	$398,000
Manufactured:				
Brake linings and disk brake pads[4]	NA	275,000	NA	293,000
Clutch facings and linings[5]	NA	23,300	NA	28,600
Clothing, cord, fabric, yarn	NA	2,110	NA	--
Gaskets, packing and seals	NA	1,810	NA	1,480
Panel, sheet, tile, tube[6]	NA	27,700	NA	39,700
Paper and millboard	NA	860	NA	983
Other articles[7]	NA	10,200	NA	10,700
Total	NA	341,000	NA	374,000

-- Zero. NA Not available.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship value.

[3]Includes crudes, fibers, stucco, sand, and refuse. May also include nonasbestos materials.

[4]Includes asbestos and cellulose fiber brakes and similar materials.

[5]Includes clutches and other friction materials, excluding brakes and brake pads.

[6]Includes asbestos cement and cellulose fiber cement products.

[7]Includes asbestos and cellulose fiber products.

Source: U.S. Census Bureau.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF ASBESTOS FIBERS, BY TYPE AND ORIGIN[1]

	Canada		South Africa		Other		Total	
Type	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
2004:								
Chrysotile:								
Crude	254	$49	--	--	1,020	$10	1,270	$59
Spinning fibers	20	3	--	--	--	--	20	3
All other	1,650	258	122	$239	45	82	1,820	579
Other, unspecified asbestos type	334	165	--	--	--	--	334	165
Total	2,260	475	122	239	1,060	92	3,450	806

See footnotes at end of table.

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TABLE 6—Continued

U.S. IMPORTS FOR CONSUMPTION OF ASBESTOS FIBERS, BY TYPE AND ORIGIN[1]

Type	Canada		South Africa		Other		Total	
	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
2005:								
Chrysotile:								
Crude	288	54	--	--	--	--	288	54
Spinning fibers	20	3	--	--	--	--	20	3
Milled, grade 4	--	--	32 [3]	157 [3]	266	562	298	719
All other	1,510	366	--	--	--	--	1,510	366
Other, unspecified asbestos type	417	278	--	--	--	--	417	278
Total	2,240	701	32 [3]	157 [3]	266	562	2,530	1,420

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]U.S. customs declared value.

[3]These are probably transhipments of chrysotile from Zimbabwe through South Africa.

Source: U.S. Census Bureau.

TABLE 7

U.S. IMPORTS OF PRODUCTS WITH BASIS OF ASBESTOS, CELLULOSE, OR OTHER MINERALS IN 2005

HTS[1] code	Category	Quantity (metric tons)	Value	Major sources[2]	Percentage of category total[3]
2524.00.00.00	Asbestos	2,530	$1,420,000	Canada	88% of weight.
6811.10.00.00	Corrugated cement sheet[4]	705	421,000	Finland[5], Denmark[5]	80% of weight.
6811.20.00.00	Flat cement panel, sheet, and tile[4]	91,400	38,200,000	Mexico, Canada, Chile, Malaysia	94% of weight.
6811.30.00.00	Cement pipe, tube, and pipe fittings[4]	353	171,000	Mexico	99% of weight.
6811.90.00.00	Other cement products[4]	3,070	2,300,000	Japan	88% of weight.
6812.50.00.00	Fabricated asbestos fibers; clothing[6]	9	50,500	Denmark[5]	82% of value.
6812.60.00.00	Felt, millboard, and paper	NA	9,230	Denmark[5], Japan	100% of value.
6812.70.00.00	Compressed asbestos fiber jointing	NA	694,000	Canada	87% of value.
6812.90.01.01	Other, miscellaneous[6]	1	5,070	China	100% of value.
6812.90.01.02	Yarn and thread[6]	99	437,000	Mexico	100% of value.
6812.90.01.03	Cord and string[6]	1	30,500	Japan, Taiwan, Germany	83% of value.
6812.90.01.04	Woven or knitted fabric[6]	50	460,000	South Africa	99% of value.
6812.90.01.10	Articles for use in civil aircraft[6]	NA	16,700	Japan, United Kingdom[5], Germany[5], France	100% of value.
6812.90.01.20	Gaskets, packing, and seals[6]	154	934,000	India, Japan	60% of value.
6812.90.01.25	Other, building materials[6]	NA	144,000	Australia	98% of value.
6812.90.01.55	Other, fabricated asbestos fiber[6]	NA	130,000	France, United Kingdom[5]	74% of value.
6813.10.00.10	Brake lining and pads, civil aircraft[7]	NA	3,600,000	France[5], United Kingdom[5]	95% of value.
6813.10.00.50	Brake lining and pads, other[7]	NA	110,000,000	Brazil, China, Canada	71% of value.
6813.90.00.10	Other, articles, civil aircraft[7]	NA	332,000	United Kingdom[5]	92% of value.
6813.90.00.50	Other, friction materials[7]	NA	25,700,000	United Kingdom[5], Japan, Mexico	84% of value.
8708.31.00.00	Mounted brake linings for tractors	NA	601,000	Germany[5], Taiwan	52% of weight.
8708.31.50.00	Mounted brake linings, other	NA	395,000,000	Japan[5], Canada	60% of weight.

NA Not available.

[1]Harmonized Tariff Schedule of the United States.

[2]Countries are listed in decreasing order.

[3]Percentage contribution of total imports by major import sources, by weight or value.

[4]Articles of asbestos-cement, of cellulose fiber-cement or the like.

[5]Source likely a supplier of nonasbestos products only.

[6]Mixtures with basis of asbestos or with a basis of asbestos and magnesium carbonate.

[7]Articles with a basis of asbestos, of other mineral substances, or of cellulose.

Source: U.S. Census Bureau.

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TABLE 8

ASBESTOS: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Argentina	203	155	166	267 [r]	270
Brazil, fiber	172,695	194,750	194,350	194,800	195,000
Bulgaria[e]	350	300	300	300	300
Canada	276,790	240,500	200,500	200,000 [e]	200,000
China[e]	310,000	562,000 [r]	500,000 [r]	510,000 [r]	520,000
Colombia, crude ore	96,140	62,785	60,000 [e]	60,000 [e]	60,000
Egypt[e]	-- [r]	-- [r]	-- [r]	-- [r]	--
India[e]	21,000	18,000	19,000	18,000	19,000
Iran[e]	2,000	1,500	1,470 [r, 4]	6,000 [r, 4]	5,000
Japan[e]	-- [r]	-- [r]	-- [r]	-- [r]	--
Kazakhstan	271,300	291,100	354,500	346,500	355,000
Russia[e]	750,000	775,000	878,000 [4]	923,000 [r, 4]	925,000
Serbia and Montenegro	194	372	111 [r]	110 [r]	100
South Africa, chrysotile	13,393	--	6,218 [r]	-- [r]	-- [4]
United States, sold or used by producers	5,260	2,720	--	--	--
Zimbabwe	136,327	168,000 [e]	147,000	104,000 [r]	122,041 [4]
Total	2,060,000 [r]	2,320,000 [r]	2,360,000 [r]	2,360,000 [r]	2,400,000

[e]Estimated. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Marketable fiber production. Table includes data available through April 8, 2006.

[3]In addition to the countries listed, Afghanistan, North Korea, Romania, and Slovakia also produce asbestos, but output is not officially reported, and available general information is inadequate for the formulation of reliable estimates of output levels.

[4]Reported figure.

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BARITE

By M. Michael Miller

Domestic survey data and tables were prepared by Jeffrey A. Milanovich, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

In 2005, primary barite production (sold or used by producers) totaled 489,000 metric tons (t) valued at $17.6 million. Imports were 2.69 million metric tons (Mt), exports were 93,000 t, and apparent consumption was 3.08 Mt.

Worldwide, it is estimated that oil and gas drilling accounted for 85% to 90% of barite consumption compared with 95% in the United States. The nondrilling markets for barite are larger outside of the United States, particularly in China and Europe where there is significant barium chemicals manufacturing. Data on nondrilling uses of barite are not readily available, but based on increased drill rig activity, it is estimated that worldwide consumption of barite outside of North America increased in 2005. According to the world drill rig reports, which do not cover most of the Commonwealth of Independent States or China, the average monthly world drill rig count (excluding the United States) increased by about 13% to 1,366 rigs from an average of 1,205 in 2004. The areas that experienced the largest growth in the average number of drill rigs operating were Canada (+89), the Far East (+28), and Latin America (+26). These areas accounted for nearly 89% of the total increase (Baker Hughes, 2006§).

Barite, a name that was derived from the Greek word barus (heavy), is the mineralogical name for barium sulfate. In commerce, the mineral is sometimes referred to as barytes. As used in this report, the term primary barite refers to the first marketable product, which includes crude barite that usually has undergone simple beneficiation methods, such as washing, jigging, and tabling, or more complex methods, such as heavy media separation, flotation, and magnetic separation. Most crude barite requires some upgrading to minimum purity or density levels.

Production

Domestic production and sales data for barite were derived from voluntary responses to the U.S. Geological Survey (USGS) canvass of 33 known mines and grinding plants. The USGS received responses from 30 of the operations, representing 97% of barite sold and used by processors. Seven mines were included in the survey; five were producing, and two were idle. Of the producing mines, four were in Nevada, and one was in Georgia; the idle mines were in Nevada and Tennessee. There were 24 grinding plants operating at the end of the reporting year. The Georgia mine and three of the Nevada mines had associated nearby grinding plants, while one small Nevada mine supplied a grinding plant in California. Some of the ore from Nevada was sent for grinding to plants on the coast of the Gulf of Mexico. Most ore in Nevada was ground onsite or in California and sold into the petroleum drilling markets of the Western United States and southwestern Canada or to local industrial users.

Barite production in 2005 was 489,000 t, a decrease of 8% compared with that of 2004. The value of domestic production was $17.6 million, a decrease of about 6%, although the unit value did increase slightly. The bulk of mine production was from Nevada with a small amount reported from Georgia.

In 2005, there were 14 facilities on the coast of the Gulf of Mexico (6 in Louisiana and 8 in Texas) that produced barite to American Petroleum Institute (API) specifications (of which a minimum specific gravity of 4.20 grams per cubic centimeter is the most important). These stand-alone grinding plants received mostly relatively low-priced crude barite primarily from China and India for grinding to API specifications for the oil and gas drilling market. In Louisiana, there were two grinding plants in the Amelia/Morgan City area, one in Houma, one near the Lake Charles/Westlake area, one in New Iberia, and one near New Orleans. In Texas, there were two grinding plants in Brownsville, three in Corpus Christi, one in Galveston, and two in Houston, at least one of which, in addition to supplying the drilling market, also produced commercial filler-grade barite.

Grinding plants that produce commercial filler-grade barite or chemical-grade barite are located in northern Georgia or in the Mississippi River Valley. There were three mills and one mine in Georgia, and single mills in Illinois, Missouri, and Tennessee. The location of mills near the Mississippi River allowed them to receive imported barite by barge and to ship the finished product by barge, if possible, or by rail or truck to industrial users in the Midwestern United States.

In 2005, the leading barite companies that mined and ground barite in the United States were also major oil service companies and included Baker Hughes INTEQ (a division of Baker Hughes, Inc.), Baroid (the drilling fluids and industrial barite subsidiary of Halliburton Energy Services, Inc.), and M-I SWACO (a joint venture between Smith International Inc. and Schlumberger Ltd.). Baker Hughes INTEQ, Halliburton, and M-I SWACO are world renowned and operate in many countries, mining barite and providing drilling sales and services. These three companies operated barite mines with associated beneficiation mills and grinding plants in Nevada and grinding plants in Louisiana and Texas. Excalibar Minerals Inc. (a division of Newpark Resources, Inc. of Houston) was a major barite importer and grinder in Louisiana and Texas for the oil and gas drilling market. The company also operated a grinding plant in Tennessee serving nondrilling markets. There were other, smaller companies near the Gulf of Mexico that received imported barite by ship through ports in Louisiana and Texas. Ambar Drilling Fluids LP in Houma ground imported barite for its service unit. U.S. Clay LP of Birmingham, AL, ground bentonite for its own use in Brownsville and crude barite for other grinding plants (on a toll basis). The other grinding plant in Brownsville is owned by Milwhite, Inc.

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After being ground to API specifications, the barite is transferred directly to containers on barges docked in canals, lakes, and rivers near the plants for large-scale deliveries to offshore drilling platforms. These near-shoreline barite staging locations also are closer to the clusters of onshore areas with significant petroleum production in the Petroleum Administration for Defense (PAD) District 3. The PAD districts were World War II divisions of the oil-producing areas of the United States; these designations continue to be used.

The direct impact of Hurricanes Katrina (landfall on August 29, 2005, in southeastern Louisiana) and Rita (landfall on September 24, 2005, near the Louisiana-Texas border) on barite grinding facilities in the Gulf of Mexico region was relatively small. The majority of the grinding plants in Louisiana and Texas were shut down (mostly as a result of power outages) for periods ranging from a few days to a week. One Louisiana plant, however, did suffer more extensive damage, but was repaired and back in production by December.

Consumption

Apparent consumption increased by 25% to 3.08 Mt in 2005 from 2.46 Mt in 2004 (table 1). Ground barite sales increased by more than 11% to 2.72 Mt in 2005 from 2.44 Mt in 2004. In 2005, sales by grinding plants in Louisiana increased by 12% to 1.18 Mt, and in Texas, by 24% to 934,000 t, while sales by grinding plants in all other States decreased by about 5% to 612,000 t (table 2). About 2.6 Mt, or nearly 95%, of barite sales from domestic crushers and grinders was for petroleum well-drilling markets, and the remaining 5% was for industrial end uses (table 3).

Barite used for drilling petroleum wells can be black, blue, brown, buff, or gray depending on the ore body. Most barite needs to be ground to a small uniform size before it is used as a weighting agent in petroleum well-drilling mud based on specifications set by the API or the former Oil Companies' Materials Association (OCMA).

The barite is finely ground so that at least 97% of the material, by weight, can pass through a 200-mesh (Tyler) [75-micrometer (μm)] screen, and no more than 30%, by weight, can be less than 6 μm, effective diameter, which is measured using sedimentation techniques. The ground barite also must be dense enough so that its specific gravity is 4.2 or greater, soft enough to not damage the bearings of a tricone drill bit, chemically inert, and containing no more than 250 milligrams per kilogram (mg/kg) of soluble alkaline salts (American Petroleum Institute, 1993, p. 6-11). A small percentage of iron oxide is allowable. An additional benefit of barite is noninterference with magnetic measurements taken in the borehole, either during logging-while-drilling or in separate drill hole logging.

In an effort to extend barite reserves in Nevada and to hold down future price increases, M-I SWACO has proposed the reduction of the API specific gravity requirement on barite to 4.1 from 4.2. The company performed an engineering analysis that showed that, on a highly weighted drilling mud, only about an additional 1% of barite will be required to achieve the desired mud weight and that there are no effects on the performance of the typical drilling fluid system. As a result, the company announced that, beginning in January 2006, it would be introducing a new optional grade of barite that would meet API technical standards and quality control but with a minimum density specification of 4.1. The company believes that, once the 4.1 material gains acceptance, it will become the norm, and 4.2 barite will be a premium product used for critical applications. The added cost of using more barite per barrel of drilling mud would be offset by a lower price for the 4.10-grade barite (Newcaster, 2006).

According to M-I SWACO projections, economic 4.2-grade reserves in Nevada will be depleted by 2011, but the company is of the opinion that Nevada has numerous viable prospects for 4.1-grade barite that can be exploited economically. The company believes that, with the introduction of and significant shift to the 4.1 product, coupled with a modest industry investment, the reserves could be extended and would allow production to continue at current levels out to about 2016. If the 4.2 standard is not changed, as reserves decrease, M-I SWACO forecast that the industry will need to invest $100 million to ensure 20 more years of 4.2-grade material.

Hurricanes Katrina and Rita caused damage to drill rigs operating in the Gulf of Mexico, but at the end of the year, the total number of oil and gas rigs operating in the United States was 1,471. This was an increase of more than 18% compared with 2004's end-of-year rig count of 1,243. This large increase in drill rigs exploring for oil and gas was the result of high oil and gas prices, which temporarily rose even higher in the aftermath of the hurricanes. Fueled by the dramatic increase in oil and gas prices, the increase in domestic exploration (especially for natural gas) has followed suit. The total U.S. rig count has increased by more than 70% in the past 3 years (December 2002 to December 2005), and this increased drilling activity has pushed domestic barite production up by 16% and imports of crude barite up by 74% during the same period. During the same 3-year period, the international rig count (excluding the United States) has increased by 26%. Since 1998, consumption of barite in well drilling in the United States has been driven more by the demand for natural gas than for oil. At the end of 2005, 84% of drill rigs operating in the United States (onshore and offshore) were drilling for gas (Baker Hughes, 2006§[1]). According to the U.S. Department of Energy, Energy Information Administration (2006a§), the estimated annual average wellhead price of natural gas was $7.51 per thousand cubic feet, up from the $5.46 per thousand cubic feet average for 2004. Continued high prices for natural gas and strong U.S. demand during the year helped fuel the high level of domestic drilling activity, which resulted in increased consumption of barite.

In 2005, sales of domestic and imported barite sold for industrial uses was essentially unchanged at 141,000 t (table 3). Industrial end uses, such as barium chemicals (the largest by volume is barium carbonate), filler in paint and plastics, and powder coatings, require the barite to be ground to a small uniform size. The size depends on the use, but for paint- and plastic-grade material, it averages about 2 to 3 μm. Barite-

[1]References that include a section mark (§) are found in the Internet References Cited section.

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containing materials that are used for sound reduction in engine compartments are gaining market share among automotive manufacturers. Barite also is used in the base coat of automobile finishes for smoothness and corrosion resistance and continues to be used in friction products for automobiles and trucks.

Barite that is used as an aggregate in "heavy" cement or radiation shielding cement is crushed and screened to sizes ranging from 4.75 millimeters (0.187 inches) to 3.75 centimeters (1.5 inches) for the coarse grade. New Riverside Ochre Co., Inc. in Georgia is the primary supplier of barite aggregate.

Foreign Trade

Barite exports during 2005 increased by about 33% to 92,700 t. About 94% of the total was exported to Canada, about 5% went to Mexico, and the bulk of the remaining 1% went to Venezuela (table 4). Imports of crude natural barite [Harmonized Tariff Schedule of the United States (HTS) code 2511.10.5000] increased by more than 31% to 2.57 Mt; imports came from China (88%), India (11%), and Morocco (1%). Demand for drilling grade barite was so strong that imports of ground barite (HTS 2511.10.1000) increased to 84,000 t in 2005 from 5,100 t in 2004. Imports for the several forms of barite reported under the HTS nomenclature "Other sulfates of barite" decreased by about 16% to 28,600 t (table 5). Crude natural barite was imported into the United States through ports in Louisiana (1.77 Mt), Texas (758,000 t), and California (37,500 t).

Prices

The average sales value per ton for primary barite from mines and their associated beneficiation plants in the United States increased to $35.92 per metric ton, a slight increase compared with the value of $35.08 in 2004 (table 1). The average sales value for drilling-grade barite ground in Louisiana increased by about 7% to $89.83 per ton. The sales value of barite ground in Texas (of which nearly 99% was drilling grade) was essentially unchanged at $85.79 per ton and that of the other States was essentially unchanged at $84.69 per ton compared with the 2004 values (table 2). Barite for barium chemicals, filler and extender, and glass decreased by about 3% to about $195 per ton for 2005 (table 3).

According to Industrial Minerals (2005), at yearend, U.S. import prices for API grade, lump, including cost, insurance, and freight, U.S. Gulf Coast, decreased to $58 to $60 per ton for Chinese barite, while prices for Indian barite were unchanged at $69 to $71 per ton. Moroccan barite was listed at $67 to $69 per ton. Ground, OCMA, bulk, delivered to Aberdeen [United Kingdom] increased by £10 per ton to £60 to £65 per ton (about $105 to $113 per ton based on the average December 2005 exchange rate). Micronized, off white, minimum 99% less than 20 μm, delivered to the United Kingdom also was unchanged at £140 to £150 per ton (about $244 to $262 per ton).

World Review

China.—China is the leading exporter of barite and for many years has been the low-cost supplier in world markets. However, from December 2003 to December 2005, the published import price of Chinese barite increased by about 33%, and prices for barite from the other major exporting countries (India and Morocco) rose similarly. The factors that pushed up Chinese prices were high ocean freight costs, port congestion, problems with internal freight logistics, and the lowering of the tax rebate on barite exports.

Kazakhstan.—As a result of the boom in oil and gas exploration and development in Kazakhstan and the surrounding region in recent years, the country has increased production of barite ore and barite concentrates. The barite producers include LLC Barite-Oil-Kentau and JSC Yuzhpolimetall (Kentau Branch) in Yuzhno-Kazakhstansky Oblast, JSC Vostochnoe Rudoupravlenie and LLC Zhartas in Zhambyl Oblast, and JSC Zhalair in Karaganda Oblast. In 2005, production of concentrates was estimated to be 120,000 t, which would have included about 70,000 t for export and 50,000 t for domestic consumption (Petrov and Dotsenko, 2005).

Russia.—Prior to the breakup of the Soviet Union, the majority of barite consumed by Russia was supplied by Kazakhstan. In the 1990s, supplies of barite from Kazakhstan decreased significantly, which led to the development of barite deposits within the boundaries of the new Russian state. At present, there are three companies involved in mining barite and producing barite concentrates—JSC Salair GOK (in Kemerovo Oblast), PJSC Barite (in Khakassia Republic), and PJSC Khoilinsky GOK (in Komi Republic). Annual production of barite concentrates is in excess of 60,000 metric tons per year (t/yr), and the country imports an additional 20,000 to 30,000 t/yr. Consumption patterns are roughly 77% for oil and gas drilling, 10% for chemical uses, 10% for building materials, and 3% for other uses (Petrov and Dotsenko, 2005).

Outlook

Continuing the trend of recent years, barite consumption in the United States is expected to increase. Since 2002, U.S. consumption has increased by nearly 61%, driven by the Nation's demand for natural gas. Although total demand for natural gas has essentially been unchanged during the past 10 years, it still totaled nearly 22 trillion cubic feet of gas in 2005. More importantly, the average annual wellhead price for natural gas has increased by more than 240% since 1999, which has made exploration for and development of domestic gas economic (if not highly profitable). The increase in natural gas prices has led some consumers to switch to alternative fuels where possible, which explains the flat demand even though the economy has grown dramatically during the same time period. The short-term domestic forecast for natural gas demand calls for a 1.7% decrease in 2006 but an increase of 4.2% in 2007, although severe winter weather could change these forecast numbers (U.S. Department of Energy, Energy Information Administration, 2006b§). As a result, the level of drilling activity in North America is expected to remain high. In 2005, most of the drill rigs in North America were directed toward gas (84%), and that trend is expected to continue. Through the first half of 2006, the U.S. rig count continued to rise and averaged 1,576 rigs per month (Baker Hughes, 2006§).

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The U.S. Congress has been working on legislation to open up previously closed areas of the outer continental shelf to oil and gas exploration. If these areas are opened, the increase in drilling will be even more dramatic, and demand for barite will rise accordingly.

If the information on the depletion of Nevada reserves is borne out, then failure to lower the API-specific gravity specification will likely result in higher prices and greater reliance on imports. There is some indication that high-grade ores are being depleted in other producing countries. The United States is already importing more than 80% of the barite consumed annually. Reduced domestic production of barite would not only increase the Nation's reliance on imports but would also increase the cost of oil and gas exploration in the Western United States by increasing the delivered cost of barite, which would have to be shipped from grinding plants in Louisiana and Texas.

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TABLE 1
SALIENT BARITE STATISTICS[1]

(Thousand metric tons and thousand dollars)

	2001	2002	2003	2004	2005
United States:					
Barite, primary:					
Sold or used by producers:					
Quantity	400	420	468	532	489
Value	11,000	12,200	13,900	18,700	17,600
Exports:					
Quantity	45	47	44	70	93
Value	5,330	4,230	4,620	6,400	9,930
Imports for consumption:[2]					
Quantity	2,510	1,540	1,650	2,000	2,690
Value	125,000	81,300	85,500	109,000	162,000
Consumption, apparent[3]	2,870	1,920	2,080	2,460	3,080
Crushed and ground, sold or used by processors:[4]					
Quantity	2,670	1,980	2,230	2,440	2,720
Value	206,000	151,000	165,000	208,000	238,000
World, production	6,780 r	6,490 r	6,790 r	7,440 r	7,870 e

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits.

[2]Includes crude, ground, and other barite imports.

[3]Sold or used plus imports minus exports.

[4]Includes imports.

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TABLE 2
CRUSHED AND GROUND BARITE SOLD OR USED BY PROCESSORS IN THE UNITED STATES, BY STATE[1, 2]

State	2004 Number of plants	2004 Quantity (thousand metric tons)	2004 Value (thousands)	2005 Number of plants	2005 Quantity (thousand metric tons)	2005 Value (thousands)
Louisiana	6	1,050	$88,400	6	1,180	$106,000
Texas	8	753	64,900	8	934	80,100
Other[3]	10	641	54,300	10	612	51,800
Total	24	2,440	208,000	24	2,720	238,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes imports.
[3]Includes California, Georgia, Illinois, Missouri, Nevada, and Tennessee.

TABLE 3
CRUSHED AND GROUND BARITE SOLD OR USED BY PROCESSORS IN THE UNITED STATES, BY USE[1, 2]

(Thousand metric tons and thousand dollars)

Use	2004 Quantity	2004 Value	2005 Quantity	2005 Value
Barium chemicals, filler and/or extender, glass	142	28,400	141	27,400
Well drilling	2,300	179,000	2,580	210,000
Total	2,440	208,000	2,720	238,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes imports.

TABLE 4
U.S. EXPORTS OF NATURAL BARIUM SULFATE (BARITE), BY COUNTRY[1]

Country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Azerbaijan	40	$5	--	--
Brazil	9	3	25	$8
Canada	61,800	4,850	86,700	7,870
China	--	--	103	77
Colombia	--	--	5	3
Costa Rica	133	71	76	41
Czech Republic	8	63	--	--
Ecuador	6	36	--	--
France	10	33	--	--
Germany	8	46	--	--
Greece	2	7	1	4
Hong Kong	11	38	--	--
India	--	--	3	8
Japan	110	94	37	37
Korea, Republic of	5	3	--	--
Kuwait	54	9	--	--
Mexico	7,580	956	4,340	1,130
Philippines	49	60	10	20
Senegal	103	16	--	--
Singapore	--	--	45	8
South Africa	1	3	--	--
Taiwan	--	--	16	46
Thailand	14	63	--	--
United Kingdom	3	20	--	--
Venezuela	53	20	1,320	677
Total	69,900	6,400	92,700	9,930

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF BARITE, BY COUNTRY[1]

Country	2004 Quantity (metric tons)	2004 Value[2] (thousands)	2005 Quantity (metric tons)	2005 Value[2] (thousands)
Crude:				
China	1,800,000	$83,000	2,280,000	$120,000
India	156,000	7,610	276,000	16,500
Mexico	--	--	90	6
Morocco	--	--	19,800	1,280
Total	1,960,000	90,600	2,570,000	137,000
Ground:				
China	4,630	651	14,400	1,520
India	--	--	44,500	4,230
Japan	--	--	214	32
Mexico	475	49	280	30
Morocco	--	--	24,600	2,440
Total	5,100	700	84,000	8,250
Other sulfates of:				
Belgium	20	14	210	119
Canada	920	729	106	38
China	17,400	3,670	13,700	3,550
Finland	(3)	2	1	32
France	--	--	20	12
Germany	10,300	9,390	9,900	8,570
India	1	5	--	--
Italy	4,040	2,350	3,910	2,410
Japan	884	1,530	509	1,070
Mexico	--	--	108	61
Spain	246	170	148	169
Switzerland	--	--	9	6
Total	33,800	17,800	28,600	16,000

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Cost, insurance, and freight value.
[3]Less than ½ unit.

Source: U.S. Census Bureau adjusted by the U.S. Geological Survey.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF BARIUM CHEMICALS[1]

	2004 Quantity (metric tons)	2004 Value[2] (thousands)	2005 Quantity (metric tons)	2005 Value[2] (thousands)
Chloride	130	$135	94	$138
Oxide, hydroxide, peroxide	3,540	3,360	3,760	3,780
Nitrate	4,300	5,910	3,280	8,570
Carbonate, precipitated	10,200	5,190	6,920	4,150

[1]Data are rounded to no more than three significant digits.
[2]Cost, insurance, and freight value.

Source: U.S. Census Bureau.

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TABLE 7
BARITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005[e]
Afghanistan[e, 3]	2,000	2,000	2,000	2,000	1,500
Algeria	43,020	51,733	45,649	47,945	52,813 [p, 4]
Argentina	6,955	3,048	6,934 [r]	2,762 [r]	3,000
Australia[e]	20,000	20,000 [r]	20,000	20,000	20,000
Belgium[e]	30,000	30,000	30,000	30,000	30,000
Bolivia	6,253	15,556	1,851	5,774 [r]	5,800
Bosnia and Herzegovina[e]	2,000	2,000	1,851 [4]	1,900 [4]	1,900
Brazil, beneficiated	54,790	53,098 [r]	57,452 [r]	59,612 [r]	60,500 [p]
Bulgaria[e, 5]	125,000	100,000	95,000	95,000	95,000
Burma	31,015 [r]	15,050	4,850 [r]	2,224 [r]	3,000
Canada	23,000	17,417 [r]	27,369 [r]	20,601 [r]	21,000 [p]
Chile	584	384	229	31 [r]	30
China[e]	3,600,000	3,100,000	3,600,000 [r]	3,900,000	4,200,000
Colombia[e]	600	600	600	600	600
Ecuador	1,181	1,180 [e]	2,139	2,350	2,400
Egypt[e]	500	500	500	500	500
France	81,000	80,000	81,000	82,000 [e]	82,000
Georgia[e]	15,000	15,000	15,000	15,000	15,000
Germany, marketable Ba_2SO_4	108,100	100,993 [r]	109,506 [r]	93,624 [r]	95,000
Greece, crude ore[e]	800	800	800	800	800
Guatemala[e]	700 [4]	100	100	70 [r, 4]	70
India[e]	850,000	916,000	675,000	723,000	1,000,000
Iran[3]	195,539	178,652	196,169 [r]	275,607 [r]	280,000
Italy[e]	25,000	25,000	25,000	25,000	12,000
Kazakhstan[6]	72,000 [r]	79,000 [r]	79,000 [r]	120,000 [r]	120,000
Korea, North[e]	70,000	70,000	-- [r]	-- [r]	--
Korea, Republic of	200 [r]	78 [r]	140 [r]	50 [r]	100
Laos	3,300 [r]	12,695	18,070	10,470 [e]	15,000
Malaysia	649	3,082	--	-- [e]	--
Mexico	142,017	163,620	287,451	306,668 [r]	274,700
Morocco	471,102	469,934	358,500 [r]	355,800 [r]	360,000
Nigeria[e, 7]	5,000	5,000	5,000	5,000	5,000
Pakistan[e]	27,200 [r]	26,100 [r]	40,800 [r]	44,200 [r]	44,000
Peru	11,031	3,806	2,906	3,606 [r]	3,700 [4]
Poland	2,500	2,700	3,000 [e]	3,000 [e]	2,500
Romania, processed	2,849	100	2,000 [e]	8,000 [e]	5,000
Russia[e]	64,000 [r]	59,000 [r]	78,000 [r]	63,000 [r]	63,000
Saudi Arabia[e]	9,000	9,000	9,000	10,000	--
Slovakia, concentrate	14,000	11,000	14,000 [e]	14,000 [e]	10,000
Spain, marketable Ba_2SO_4	50,640	52,494	44,660	45,000 [e]	45,000
Thailand	23,559	137,469	115,600	211,278 [r]	120,000
Tunisia	2,208	5,539	3,000	1,813 [r]	--
Turkey	57,373	106,843	119,648	134,504 [r]	155,000
United Kingdom[e]	55,000	66,000	59,000	60,000	60,000
United States[8]	400,000	420,000	468,000	532,000	489,000
Vietnam	71,114	60,228	81,456	101,040	116,000 [4]
Total	6,780,000 [r]	6,490,000 [r]	6,790,000 [r]	7,440,000 [r]	7,870,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 10, 2006.

[3]Data are for fiscal year beginning March 21 of that stated.

[4]Reported figure.

[5]Marketable concentrate based on reported or estimated noncountry data but is in accord with the trends in reported Bulgarian raw barite production.

[6]Estimated marketable barite, however, reported figures are as follows, in metric tons: 2001—154,200; 2002—154,500; 2003—214,200; 2004—310,700; and 2005—251,000.

[7]Considerably more barite is produced, but it is considered to be commercially unusable.

[8]Sold or used by producers.

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BAUXITE AND ALUMINA

By Patricia A. Plunkert

Domestic survey data and tables were prepared by Benjamin S. Goff, statistical assistant, and the world production tables were prepared by Regina R. Coleman, international data coordinator.

Bauxite is a naturally occurring, heterogeneous material comprised primarily of one or more aluminum hydroxide minerals plus various mixtures of silica (SiO_2), iron oxide (Fe_2O_3), titania (TiO_2), aluminosilicates (clay, etc.), and other impurities in trace amounts. The principal aluminum hydroxide minerals found in varying proportions within bauxite are gibbsite [$Al(OH)_3$] and the polymorphs, boehmite and diaspore [both AlO(OH)].

Bauxite is typically classified according to its intended commercial application, such as abrasive, cement, chemical, metallurgical, and refractory. Of all bauxite mined, approximately 85% is converted to alumina (Al_2O_3) for the production of aluminum metal, and an additional 10% is converted to various forms of specialty alumina for nonmetal uses. The remaining 5% is used directly for nonmetallurgical bauxite applications. The bulk of world bauxite production is used, therefore, as feed for the manufacture of alumina via a wet chemical caustic leach process known as the Bayer process. Most of the alumina produced from this refining process is smelted using the Hall-Héroult process to produce aluminum metal by electrolytic reduction in a molten bath of natural or synthetic cryolite (Na_3AlF_6).

Specifications for the nonmetallurgical grades of bauxite are more stringent than those for bauxite used to produce alumina and are based on the processing requirements and special properties required of their final commercial products. The natural chemical impurities that exist within these specialty-grade ores are not chemically removed by refining because the ores are used as direct feed for the production of their ultimate end products. Although global figures on nonmetallurgical bauxite production and consumption are not commonly available, the principal industrial end uses are considered to be in refractories and abrasives, followed by cement applications. In addition, the aluminum chemicals and steel industries also consume significant quantities of bauxite.

Twenty-two countries reported bauxite mine production in 2005, and total world production increased by about 6% compared with that of 2004 (table 11). Australia, Brazil, China, Guinea, and Jamaica accounted for about three-fourths of the total bauxite mined in 2005.

At the current rate of consumption, total reported world reserves of bauxite are sufficient to meet cumulative world primary aluminum metal demand well beyond the 21st century. Although bauxite reserves are unevenly distributed throughout the world, with approximately 90% in a dozen countries, the sheer magnitude of these reserves (25 billion metric tons) is sufficient to ensure a readily accessible supply for the future (Plunkert, 2006).

U.S. production of alumina (calcined equivalent), derived almost exclusively from imported metallurgical-grade bauxite, decreased by 3% compared with that of 2004 (table 2). An estimated 91% of the alumina shipped by U.S. refineries went to domestic primary smelters for aluminum metal production. Consumption by the abrasives, chemicals, refractories, and specialties industries accounted for the remainder of U.S. alumina shipments.

World output of alumina increased by 5% in 2005 compared with that of 2004. The principal producing countries, in descending order of alumina output, were Australia, China, Brazil, the United States, and Jamaica. These countries accounted for 66% of the world's production; Australia alone accounted for 28% of total world production (table 12).

Legislation and Government Programs

In November, the Defense Logistics Agency (DLA) released its revised Annual Materials Plan (AMP) for the National Defense Stockpile for fiscal year 2006 (October 1, 2005, through September 30, 2006). The 2006 AMP provided for the sale of up to 43,700 calcined metric tons (43,000 calcined long tons) of refractory-grade bauxite in fiscal year 2006. This was the maximum amount recommended for disposal during the fiscal year, and the actual level of sales would be limited to available inventory. The AMP also included the authority to sell 2.03 million metric tons (Mt) (2 million long tons) of Jamaica-type metallurgical-grade bauxite and 406,000 metric tons (t) (400,000 long tons) of Suriname-type metallurgical-grade bauxite. This represented inventory that had been sold previously, but not yet shipped (Defense Logistics Agency, 2005).

At yearend 2005, the uncommitted inventories for metallurgical-grade bauxite and calcined refractory-grade bauxite were depleted (Defense Logistics Agency, 2006).

Production

Bauxite.—For many years, domestic mines have supplied less than 1% of the U.S. requirement for bauxite. Essentially all the domestic bauxite production was used in nonmetallurgical products, such as abrasives, chemicals, proppants, and refractories. Thus, the United States imported almost all the bauxite, especially the metallurgical grade, that it required.

Alumina.—The two hurricanes (Katrina and Rita) that hit the Gulf Coast of the United States forced the domestic alumina refineries to curtail production for several days. Although none of the plants experienced significant damage, the temporary shutdowns were responsible for the 3% decrease in U.S. production compared with that of 2004.

Consumption

Bauxite.—Domestic production and consumption data for bauxite and alumina were obtained by the U.S. Geological

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Survey from three voluntary surveys of U.S. operations. One of these surveys, "Bauxite Consumption," was sent to 31 operations, 24 of which responded, representing 89% of the bauxite consumed for uses other than cement listed in table 4. Total domestic consumption of bauxite decreased by about 3% compared with that of 2004. In 2005, 92% of the bauxite consumed in the United States was refined to alumina (an estimated 2.3 t of dried bauxite was required to produce 1 t of alumina); the remaining 8% was consumed in nonmetallurgical applications (table 4).

Alumina.—An estimated 91% of the alumina shipped by U.S. alumina plants went to primary aluminum smelters for metal production. In 2005, 15 domestic primary aluminum smelters consumed 4.66 Mt of alumina. Consumption of various forms of alumina by the abrasives, chemicals, refractories, and specialties industries accounted for the remainder of U.S. alumina use.

Prices

Most metallurgical-grade bauxite and alumina were purchased under long-term contracts. Contract terms for these commodities normally were not made public. Spot prices for metallurgical-grade alumina and specialty forms of bauxite and alumina for nonmetallurgical applications, however, were published in trade journals.

Industrial Minerals (2005) quoted end-of-year prices for several types of imported refractory-grade bauxite from China and Guyana. The price quotes for Chinese refractory-grade bauxite, 88% Al_2O_3 free on board (f.o.b.) Chinese ports, were as follows: Shanxi, round kiln, lump, $160 to $165 per metric ton; Shanxi, rotary kiln, lump, $150 to $165 per ton; and Guizhou, rotary kiln, lump, $140 to $145 per ton. The price range for Guyanese refractory-grade bauxite was $205 to $210 per ton, cost, insurance, and freight (c.i.f.) Rotterdam, Netherlands. The 2005 annual average values of U.S. imports of metallurgical-grade bauxite are listed in table 7.

The market or spot prices for alumina fluctuated in 2005 amid continuing tight global supply and strong demand from China. According to Metal Bulletin, metallurgical-grade alumina spot prices on international markets began 2005 at $390 to $420 per ton. By mid-March, the price reached $440 to $460 per ton before beginning a slow decline to end at $400 to $420 per ton in mid-June. In mid-August, the price began to increase dramatically, and by yearend, the price had reached $580 to $590 per ton. Trade data released by the U.S. Census Bureau indicated that the 2005 annual average value of U.S. imports of calcined alumina was $305 per ton, free alongside ship (f.a.s.) port of shipment, and $316 per ton, c.i.f. U.S. ports.

Trade

In addition to the materials listed in tables 8-10, various specialty aluminum compounds were also traded. The compounds exported in 2005 included 13,900 t of aluminum oxide abrasives; 13,100 t of aluminum chloride; 12,600 t of aluminum sulfate; and 8,410 t of fluoride-base compounds of aluminum, including synthetic cryolite and aluminum fluoride. The compounds imported in 2005 included 244,000 t of aluminum oxide abrasives; 9,860 t of aluminum sulfate; 4,250 t of fluoride-base aluminum compounds; and 712 t of aluminum chloride.

World Industry Structure

In 2005, world production of bauxite increased by 6% compared with that of 2004 (table 11). Mine production was reported in 22 countries, and total world production amounted to 169 Mt. The leading producers of bauxite, in decreasing order of tonnage mined, were Australia, Brazil, China, Guinea, and Jamaica, which accounted for about three-fourths of total world production.

World output of alumina increased by 5% in 2005 compared with that of 2004 (table 12). The five principal producing countries, in descending order of quantity of alumina produced, were Australia, China, Brazil, the United States, and Jamaica. These countries accounted for about two-thirds of the world's production; Australia alone accounted for 28%.

World Review

Australia.—In March, the 1.4-million-metric-ton-per-year (Mt/yr) Comalco Alumina Refinery (CAR) was officially opened. Alumina from the refinery would be used by Comalco Ltd.'s smelters in Australia and New Zealand and also sold to a range of export customers, including Norsk Hydro ASA under a 26-year supply agreement for 500,000 metric tons per year (t/yr) of alumina (Comalco Ltd., 2005a).

Comalco also announced the construction of a new ship loader project, scheduled for completion in late 2006, at its Weipa Mine in Queensland. The new loader, rated at 6,500 metric tons per hour, would allow the operation to load two ships simultaneously. The Weipa Mine supplied 100% of the bauxite required for the CAR and the Queensland Alumina Refinery in Gladstone and the Eurallumina Refinery in Sardinia, Italy (Comalco Ltd., 2005b).

Alcan Inc. announced that it had signed a 20-year agreement with the PNG Gas Project for the purchase of natural gas for Alcan's Gove alumina refinery in the Northern Territory, which would replace imported oil as the primary energy source for the refinery. The first gas delivery was expected in 2009 (Alcan Inc., 2005c).

Alcan opened a new alumina research and development facility in Brisbane to develop new technologies and to enhance existing alumina production processes to improve productivity, environmental performance, and employee safety. Construction of the facility was jointly funded by the governments of Queensland and Australia (Alcan Inc., 2005b).

Bosnia and Herzegovina.—The Government of Bosnia and Herzegovina signed a 25-year contract with Starsped Gacko for the exploitation of bauxite mines in four Herzegovina municipalities. Starsped planned to produce 60,000 t/yr of ore and to invest in exploration of other deposits (Seeurope, 2005§[1]).

Brazil.—Participants in the Alumar consortium [Alcan (10%) (2005d), Alcoa (54%) (2005c), and BHP Billiton (36%)

[1]References that include a section mark (§) are found in the Internet References Cited section.

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(2005)], announced plans to invest in the expansion of the alumina refinery in Sao Luis, State of Maranhao. The project, which would increase capacity at the refinery to about 3.5 Mt/yr from 1.4 Mt/yr, was scheduled to begin in November and to be completed in 2008.

Companhia Vale do Rio Doce (CVRD) (2005) and Norsk Hydro ASA (2005) approved investments in the Stages 6 and 7 expansions of the Alunorte alumina refinery in the State of Para. Stages 4 and 5, scheduled to be completed in 2006, would increase capacity to 4.4 Mt/yr from 2.5 Mt/yr. Stages 6 and 7, scheduled to be completed in 2008, would each add 935,000 t/yr of capacity and would increase Alunorte's capacity to about 6.3 Mt/yr. CVRD owned 57% of Alunorte, Norsk Hydro owned 34%, and the remaining 9% was held by private companies in Brazil and Japan.

CVRD continued the development of the Paragominas bauxite mine and began the construction of a 244-kilometer pipeline to transport 14.4 Mt/yr of ore from the mine to the Alunorte refinery. Phase I of the mine development, with a production capacity of 5.4 Mt/yr of ore, was scheduled for completion in 2007. CVRD also approved the investment for the development of Phase 2 of the Paragominas Mine. The Phase 2 expansion, which would increase bauxite production capacity to 9.9 Mt/yr, was expected to be completed by 2008 (Companhia Vale do Rio Doce, 2005).

Alcoa's board of directors approved the development of the Juruti Mine in the State of Para. The mine initially was expected to produce 2.6 Mt/yr of ore as feed for the Alumar refinery. Future expansions of the mine were expected to require low incremental investments. The deposit was estimated to contain 695 Mt of ore. A fill installation permit was issued by the Para State government in August (Alcoa Inc., 2005c).

China.—In September, Aluminum Corp. of China (Chalco) began commercial production at the 800,000-t/yr expansion of its Shanxi refinery that increased the plant's capacity to 2.2 Mt/yr, making it the largest alumina refinery in China. The refinery processes Chinese bauxite using a "Bayer-Sinter" technology and produces a sandy alumina. Chalco also commissioned the 700,000-t/yr expansion at its Zhengzhou (formerly Henan) alumina plant in central China, which increased capacity to 2.1 Mt/yr of alumina (CRU Alumina Monitor, 2005a).

Chalco announced plans to begin construction of the Phase 3 expansion at its 850,000-t/yr Pingguo refinery in Guangxi Province. The expansion, which would increase capacity to about 1.8 Mt/yr, was scheduled to be completed in 2008 (CRU Alumina Monitor, 2005a).

Guangxu Guixi Huayin Aluminium Corp. [Chalco (33%), China Minmetals Corp. (33%), and Guanxi Investment Group Corp. (34%)] received approval from China's National Development and Reform Commission to begin construction of an 800,000-t/yr expansion of Guangxu's alumina refinery near Baise city in southern Guangxi Province. Upon completion, which could take 2 to 3 years, capacity at the refinery would increase to 1.6 Mt/yr (Metal Bulletin, 2005).

Yimei Group, a gas producer in Henan Province, announced the startup of commercial production at its 100,000-t/yr alumina refinery. Startup of the plant's Phase 2 expansion to 200,000 t/yr of alumina was delayed (Platts Metals Week, 2005).

Ghana.—Alcoa and the Government of Ghana signed a memorandum of understanding (MOU) to develop an integrated aluminum industry in Ghana. Alcoa and the Government would conduct feasibility studies on the projects to be completed in 2006. The studies included development of the Kibi and Nyinahin bauxite mines and construction of a 1.5-Mt/yr alumina refinery and related infrastructure. The refinery was expected to use natural gas supplied from the West Africa Gas Pipeline Project. Also included in the agreement was the initial restart of three of the five potlines at the 200,000-t/yr Volta Aluminium Co. (Valco) aluminum smelter in Tema (Alcoa Inc., 2005b).

Greece.—Alcan, which held a 60.2% interest in Aluminium de Grèce (AdG), sold a 53% controlling interest to Mytilineos Holdings S.A. According to the sales agreement, the balance of Alcan's interest (7.2%) may be sold to Mytilineos 1 year after the closing of this transaction. Included in the sale were a 750,000-t/yr alumina refinery and a 160,000-t/yr aluminum smelter (Alcan Inc., 2005a).

Guinea.—The Government of Guinea ratified Global Alumina Corp.'s basic agreement for the development and construction of a 2.8-Mt/yr alumina refinery in Boke. The agreement granted Global Alumina rights to construct, operate, and maintain an alumina refinery in Guinea, rights to a mining concession for the exploitation of bauxite, rights to use existing road, rail, and port infrastructure, as well as investment protections and fiscal incentives (Global Alumina Corp., 2005c). Dubai Aluminium Co. Ltd. (Dubal) and China Aluminium Group (CAG) each entered into a long-term purchase agreement for 25% of Global Alumina's annual production. In addition, Dubal and CAG would be given the opportunity to make substantial equity investments in Global Alumina (Global Alumina Corp., 2005a, b).

Halco (Mining) Inc. and the Government of Guinea reached an agreement on bauxite mining rights. Halco owned 51% of Compagnie des Bauxites de Guinée (CBG), which mined bauxite in the Boke region of Guinea and had exclusive rights to bauxite reserves and resources in northwestern Guinea through 2038. The Government, CBG, and Global Alumina entered a three-party agreement granting mining rights to part of the Initial Territory held by CBG to Global Alumina. In return, CBG, Halco, and the Government were to meet to recommend the granting of additional mining titles for 2 billion metric tons of bauxite reserves to CBG to compensate CBG for the bauxite reserves granted to Global Alumina and to provide additional tonnage to CBG for long-term needs in areas outside of CBG's Initial Territory. The additional tonnage would provide bauxite resources for export and future in-country refining needs (Alcoa Inc., 2005f).

Alcan, Alcoa, and the Government of Guinea signed a basic agreement that set forth the framework for development of a 1.5-Mt/yr alumina refinery with provisions for future expansion. Under the terms of the agreement, Alcan and Alcoa would hold at least an 80% interest in the refinery with an option for the Government to acquire an equity stake. CBG would supply the refinery with bauxite, and the project would have access to the existing infrastructure (Alcoa Inc., 2005a).

India.—Dubal finalized a $3.6 billion agreement with Larsen & Toubro Ltd. for the construction of an integrated aluminum complex in Orissa. Dubal would hold a 74% stake

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in the project, and Larsen & Toubro would hold the remainder. Phase I included a 1.4-Mt/yr alumina refinery, a bauxite mine with associated infrastructure, and a powerplant. Construction was expected to begin in 2007 with completion scheduled for 2009. Phase 2 of the project included a doubling of the refinery capacity and construction of a primary aluminum smelter. No date was given for the start of Phase 2 (Mason, 2005).

Vedanta Resources plc, majority owner of Sterlite Industries Ltd., began construction of a 1.4-Mt/yr alumina refinery in Orissa. The project was expected to be completed in 2007 (Kassakovich, 2005).

Hindalco Industries Limited, a member of Aditya Birla Group, signed a MOU with the government of Orissa to construct an integrated aluminum complex. The project included a 1-Mt/yr alumina refinery, a 260,000-t/yr aluminum smelter, a captive powerplant, and bauxite mines with a capacity of 3 Mt/yr (Aditya Birla Group, 2005§).

Jamaica.—Alcoa's board of directors approved the 1.5-Mt/yr expansion of the Jamalco alumina refinery, thereby increasing the plant's capacity to 2.8 Mt/yr. The first phase of this expansion (150,000 t/yr) was expected to be completed by yearend 2006. Phase 2 (the remaining 1.35 Mt/yr) was scheduled to be completed by yearend 2007, pending final agreements on the supply of natural gas to the refinery (Alcoa Inc., 2005d).

Kazakhstan.—Aluminum of Kazakhstan announced plans to begin development of the Vostochno-Ayatskoye bauxite deposit. The company reported reserves of 28.8 Mt of bauxite (Interfax Mining & Metals Report, 2005).

Russia.—RUSAL and SUAL Group signed an agreement that made them equal partners in the Komi Aluminium Project. The project involved the development, construction, and operation of a bauxite-alumina complex in the Komi Republic. Under the terms of the agreement, financing of a new 1.4-Mt/yr alumina refinery near the city of Sosnogorsk would be shared on a parity basis by means of debt and shareholders' capital. The refinery, scheduled to be completed by yearend 2008, would process bauxite ore extracted from the Middle Timan bauxite deposit. Production from the mine was expected to increase to 6 Mt of ore by 2008 from 1.5 Mt in 2005 (SUAL Group, 2005b).

SUAL resumed production at the Novo-Kalyinskaya Mine. Construction at the mine was suspended in the late 1980s, and the mine was temporarily closed. The mine was expected to extract 170,000 t of bauxite by yearend 2005 with production slowly increasing to about 800,000 t/yr (SUAL Group, 2005a).

In December 2004, RUSAL won a tender for the development of the Denislavsky, Ixinsky, and Plesetsky areas of the North Onega bauxite deposit. Under the provisions of the license agreement for the Ixinsky area, technical parameters for development of the area were to be prepared no later than September 2007, and construction of the infrastructure was to begin by December 2007. Mine production was expected to begin by January 2010 and to increase to 1.5 Mt/yr within 2 years. In accordance with the agreement, RUSAL must complete a feasibility study for a 1.5-Mt/yr alumina refinery (with possible future expansion to 2.8 Mt/yr) by February 2007 (RUSAL, 2005).

Serbia and Montenegro.—Salamon Enterprises (a subsidiary of RUSAL) purchased a 65.4% interest in the Kombinat Aluminijuma Podgorica (KAP) aluminum complex and a 32% interest in the Ridnik Boksita Niksic bauxite mine in Montenegro. The KAP complex included a 125,000-t/yr aluminum smelter and a 280,000-t/yr alumina refinery (CRU Alumina Monitor, 2005b).

Sierra Leone.—The Government of Sierra Leone and Titanium Resources Group Ltd. (TRG) announced the restart of mining at TRG's wholly owned bauxite operations Sierra Minerals Holdings I, Ltd. (SML). Bauxite production at the rate of 1.2 Mt/yr was expected to begin in the first quarter of 2006. TRG signed long-term sales agreements with Alcoa and Glencore AG for the full estimated annual production. In January, SML was granted a 10-year mining lease with the option to renew for another 10 years. Bauxite reserves were estimated to be 12.4 Mt, which should support mining operations for about 10 years; however, it was anticipated that future exploration work in the area would expand these reserves (Titanium Resources Group Ltd., 2005).

Suriname.—In February, Suriname Aluminum Company, L.L.C. (Suralco) completed the 250,000-t/yr expansion of its refinery in Paranam 6 months ahead of schedule. The expansion increased the plant's capacity to about 2.2 Mt/yr (Alcoa Inc., 2005e).

Outlook

Several new bauxite deposits around the world are being explored and developed. Additional alumina refinery capacity is coming onstream. As a result, bauxite and alumina production was expected to be adequate to meet the long-term needs of the aluminum industry. Alumina shortages, which led to a rapid increase in price in 2005, have begun to ease and prices have moderated. Growth in demand for aluminum metal was expected to continue to increase during the next few years but at a slightly slower pace than that of the past year or two. Hence, bauxite and alumina production was expected to be adequate to meet the increased demand.

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TABLE 1
SALIENT BAUXITE STATISTICS[1]

(Thousand metric tons)

	2001	2002	2003	2004	2005
United States:					
Production, crude ore, dry equivalent:					
Quantity	NA	NA	NA	NA	NA
Value	NA	NA	NA	NA	NA
Exports, as shipped:					
Crude and dried	67	27	55	42	34
Calcined	14	15	22	21	18
Imports for consumption, as shipped:					
Crude and dried	8,300	7,340	8,390	10,000	9,850
Calcined	242	237	307	341	337
Consumption, dry equivalent	9,770	9,980	11,300	13,600 r	13,200
World, production	137,000	144,000	153,000 r	160,000 r	169,000 e

eEstimated. rRevised. NA Not available.

[1]Data are rounded to no more than three significant digits.

TABLE 2
ESTIMATED PRODUCTION AND SHIPMENTS OF ALUMINA IN THE UNITED STATES[1]

(Thousand metric tons)

			Total	
Year	Calcined alumina	Other alumina[2]	As produced or shipped[3]	Calcined equivalent
Production:				
2004	4,990	529	5,520	5,350
2005	4,750	708	5,460	5,220
Shipments:				
2004	5,000	716	5,720	5,490
2005	4,760	658	5,420	5,190

[1]Data are rounded to no more than three significant digits.

[2]Trihydrate, activated, tabular, and other aluminas. Excludes calcium and sodium aluminates.

[3]Includes only the end product if one type of alumina was produced and used to make another type of alumina.

TABLE 3
CAPACITIES OF DOMESTIC ALUMINA PLANTS, DECEMBER 31[1, 2]

(Thousand metric tons per year)

Company and plant	2004	2005
Alcoa Inc., Point Comfort, TX	2,300	2,300
BPU Reynolds, Inc., Corpus Christi, TX	1,600	1,600
Gramercy Alumina LLC, Gramercy, LA[3]	1,250	1,250
Ormet Corp., Burnside, LA	600	600
Total	5,750	5,750

[1]Capacity may vary depending on the bauxite used.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Jointly owned by Century Aluminum Co. and Noranda Aluminum Inc.

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TABLE 4
U.S. CONSUMPTION OF BAUXITE, BY INDUSTRY[1]

(Thousand metric tons, dry equivalent)

Industry	2004	2005
Abrasive	53	26
Alumina	12,500	12,200
Cement[2]	486 r	542
Chemical	W	W
Refractory	260	187
Other[3]	258	271
Total	13,600 r	13,200

rRevised. W Withheld to avoid disclosing company proprietary data, included with "Other."
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Data from the D15-Cement annual survey form, U.S. Geological Survey Form 9-4041-A.
[3]Includes municipal water works, oil, and steel and ferroalloys.

TABLE 5
STOCKS OF BAUXITE IN THE UNITED STATES, DECEMBER 31[1, 2]

(Thousand metric tons, dry equivalent)

Sector	2004	2005
Producers, processors, consumers	3,120	2,730
Government	--	--
Total	3,120	2,730

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Domestic and foreign bauxite; crude, dried, calcined, activated, all grades.

TABLE 6
STOCKS OF ALUMINA IN THE UNITED STATES, DECEMBER 31[1, 2]

(Thousand metric tons, calcined equivalent)

Sector	2004 r	2005
Producers	81	64
Primary aluminum plants	876	765
Total	957	830

rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Excludes consumer stocks other than those at primary aluminum plants.

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TABLE 7
AVERAGE VALUE OF U.S. IMPORTS OF CRUDE AND DRIED BAUXITE[1]

(Dollars per metric ton)

Country	2004		2005	
	Port of shipment f.a.s.[2]	Delivered to U.S. ports c.i.f.[3]	Port of shipment f.a.s.[2]	Delivered to U.S. ports c.i.f.[3]
Australia	11.19	29.97	15.59	30.32
Brazil	22.71	36.82	25.63	39.15
Guinea	21.85	28.08	24.36	30.31
Guyana	28.41	35.26	34.63	40.47
Jamaica	18.36	22.34	19.69	23.02
Weighted average	22.50	30.80	25.87	34.54

[1]Computed from quantity and value data reported to U.S. Customs Service and compiled by the U.S. Census Bureau, Department of Commerce. Not adjusted for moisture content of bauxite or differences in methods used by importers to determine value of individual shipments.
[2]Free alongside ship valuation.
[3]Cost, insurance, and freight valuation.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF BAUXITE, CRUDE AND DRIED, BY COUNTRY[1]

(Thousand metric tons)

Country	2004	2005
Imports:		
Australia	127	232
Brazil	2,550	3,210
Guinea	2,320	2,460
Guyana	1,110	1,280
Jamaica[2]	3,340	1,760
Other	550	916
Total	10,000	9,850
Exports:		
Canada	21	27
China	(3)	--
Mexico	12	1
Other	9	5
Total	42	34

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]In 2004, exports to the United States; data from the Jamaica Bauxite Institute.
[3]Less than ½ unit.

Note: Total U.S. imports of crude and dried bauxite as reported by the U.S. Census Bureau were as follows: 2004–8.5 million metric tons (Mt) and 2005–9.45 Mt.

Sources: U.S. Census Bureau and the Jamaica Bauxite Institute.

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TABLE 9

U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF CALCINED BAUXITE, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

	2004				2005			
	Refractory grade		Other grade		Refractory grade		Other grade	
Country	Quantity	Value[2]	Quantity	Value[2]	Quantity	Value[2]	Quantity	Value[2]
Imports:								
Australia	12	1,050	80	8,010	--	--	88	10,200
Brazil	--	--	7	524	--	--	(3)	61
China	116	15,300	88	7,570	104	14,300	43	5,490
Guyana	36	4,440	--	--	38	4,790	9	564
Other	1	52	(3)	11	47	1,430	8	457
Total	165	20,800	175	16,100	188	20,500	149	16,800
Exports:								
Canada	5	648	5	306	8	809	4	242
Mexico	1	114	9	1,340	(3)	124	5	776
Other	1	199	(3)	340	(3)	117	1	258
Total	7	961	14	1,990	8	1,050	10	1,280

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Value at foreign port of shipment as reported to U.S. Customs Service.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 10
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF ALUMINA, BY COUNTRY[1]

(Thousand metric tons, calcined equivalent, and thousand dollars)

	2004		2005	
Country	Quantity	Value[2]	Quantity	Value[2]
Imports:				
Australia	816	180,000	932	231,000
Brazil	32	16,400	17	4,260
Canada	106	70,500	103	75,100
China	7	3,570	10	5,570
France	18	23,100	16	25,400
Germany	40	72,000	49	75,200
Jamaica	60	14,200	116	36,400
Japan	4	14,200	5	13,200
Suriname	543	115,000	560	139,000
Venezuela	(3)	250	27	6,360
Other	25	23,600 r	31	27,900
Total	1,650	533,000	1,860	639,000
Exports:				
Brazil	2	3,220	3	4,260
Canada	144	65,300	407	215,000
China	493	118,000	366	125,000
Finland	(3)	632	(3)	231
Mexico	54	25,800	69	39,700
Netherlands	14	10,900	20	18,800
Norway	303	62,000	104	25,600
Russia	(3)	868	(3)	1,440
Sweden	1	1,700	1	1,760
Other	217	151,000	234	199,000
Total	1,230	439,000	1,210	631,000

rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Value at foreign port of shipment as reported to U.S. Customs Service.
[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 11
BAUXITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country	2001	2002	2003	2004	2005[e]
Australia	53,799	54,135	55,602	56,593	59,959 [3]
Bosnia and Herzegovina[e]	75	113	573 [r]	480 [r]	480
Brazil	13,032 [r]	13,260 [r]	17,363 [r]	19,700 [r]	19,800 [p]
China[e]	9,800	12,000	13,000	15,000	18,000
Ghana	678	684	495	498	734 [p]
Greece	2,052	2,492	2,418	2,444	2,450
Guinea[e, 4]	15,100	15,300 [r]	15,000 [r]	15,000 [r]	15,000
Guyana[4]	1,950	1,690	1,701 [r]	1,466 [r]	1,500
Hungary	1,000	720	666	647	511
India	7,864	9,647	10,414	11,285	11,957 [3]
Indonesia	1,237	1,283	1,263	1,331	1,400
Iran	274 [r]	57 [r]	366 [r]	420 [r]	500 [3]
Jamaica[4, 5]	12,370	13,120	13,444	13,296	14,118 [3]
Kazakhstan	3,685	4,377	4,737	4,706	4,800
Malaysia	64	40	6	2 [r]	2
Mozambique	9	9	12	7	10 [3]
Pakistan[e]	9	8	8	8 [r]	9
Russia[e]	4,000	4,500	5,500	6,000	6,400
Serbia and Montenegro	610	612	540 [r]	486 [r]	610
Suriname	4,394	4,002	4,215	4,052	4,584 [3]
Turkey[6]	242	287	364	366	365
United States	NA	NA	NA	NA	NA
Venezuela	4,585	5,191	5,446	5,842 [r]	5,900
Total	137,000	144,000	153,000 [r]	160,000 [r]	169,000

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 25, 2006.

[3]Reported figure.

[4]Dry bauxite equivalent of crude ore.

[5]Bauxite processed for conversion to alumina in Jamaica plus kiln-dried ore prepared for export.

[6]Public-sector production only.

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TABLE 12
ALUMINA: WORLD PRODUCTION, BY COUNTRY[1, 2, 3]

(Thousand metric tons)

Country	2001	2002	2003	2004	2005
Australia	16,313	16,382	16,529	16,700 [4]	17,704
Azerbaijan	95	91	180	232 [r]	315
Bosnia and Herzegovina[e]	50 [4]	50	50	50	50
Brazil	3,445	3,962	5,111	5,315 [r]	5,320 [p]
Canada	1,036	1,125	1,109	1,170	1,214
China[e]	4,650	5,450	6,110	6,990 [r, 4]	8,610
France[e]	150	150	150	100	100
Germany[e]	715 [r]	720	830	835 [r, 4]	840
Greece	679	750	750	750 [e]	750 [e]
Guinea	644 [r]	724 [r]	738 [r]	779 [r]	780 [e]
Hungary[e]	300	294	300	300	300
India[e]	2,400	2,800	2,500	2,600	2,700
Iran	--	101 [r]	102 [r]	137 [r]	150 [e]
Ireland[e]	1,100	1,100	1,100	1,100	1,100
Italy[e]	500	500	500	500	500
Jamaica	3,542	3,631	3,844	4,023	4,086
Japan[5]	331	333	363 [r]	340 [e]	330 [e]
Kazakhstan	1,231	1,386	1,419	1,468	1,505
Romania	319	361	333	350 [e]	350 [e]
Russia	3,046	3,131	3,230	3,269	3,259
Serbia and Montenegro	201	237	225	245 [r]	235
Slovakia[e]	110	112	132	130	135
Slovenia[e]	34	30	30	30	30
Spain[e, 6]	1,100	1,100	1,100	1,100	1,100
Suriname[e]	1,900	1,900	2,004 [r, 4]	2,039 [r, 4]	1,950
Turkey	146	152	162	170 [e]	170 [e]
Ukraine	1,343	1,351	1,434	1,563	1,632
United Kingdom	84	74	--	-- [e]	-- [e]
United States	4,340	4,340	4,860	5,350	5,220
Venezuela	1,833	1,901	1,882 [r]	1,900 [e]	1,920 [p]
Total	51,600	54,200	57,100	59,500 [r]	62,400

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]Figures represent calcined alumina or the total of calcined alumina plus the calcined equivalent of hydrate when available; exceptions, if known, are noted.

[2]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[3]Table includes data available through July 25, 2006.

[4]Reported figure.

[5]Data presented are for alumina used principally for specialty applications. Information on aluminum hydrate for all uses is not adequate to formulate estimates of production levels. Production of aluminum hydroxide, in metric tons: 2001—739,000 (revised); 2002—724,000 (revised); 2003—740,000; 2004—730,000 (estimated); and 2005—740,000 (estimated).

[6]Hydrate.

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BERYLLIUM

By Kim B. Shedd

Domestic survey data and tables were prepared by Amy C. Tolcin, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

The United States was the world's leading beryllium ore producer in 2005. U.S. mine shipments of beryllium ore increased from those of 2004; ore consumption for the production of beryllium hydroxide also increased (table 1). The Defense National Stockpile Center (DNSC) of the U.S. Department of Defense offered and sold selected beryllium materials from the National Defense Stockpile (NDS). On the basis of estimated contained beryllium, total U.S. imports of beryllium materials were higher and total U.S. exports were lower than those of 2004.

Beryllium is gray in color and one of the lightest metals. Its other physical and mechanical properties—outstanding stiffness-to-weight and strength-to-weight ratios, one of the highest melting points of all light metals, high specific heat, excellent thermal conductivity, outstanding dimensional stability over a wide range of temperatures, the lowest neutron absorption cross section of any metal and a high neutron-scattering cross section, and transparency to x rays—make it useful for many applications. Beryllium is used primarily as beryllium-copper alloys, beryllium oxide ceramics, and beryllium metal in a wide variety of products in aerospace, automotive, computer, defense, electronics, heavy machinery, home appliance, industrial component, instrumentation and control system, medical, nuclear, oil and gas drilling, plastic molding, telecommunications, undersea and marine, and other applications.

Only two beryllium minerals are of commercial importance for the production of beryllium. Bertrandite, which contains less than 1% beryllium, is the principal beryllium mineral mined in the United States. Beryl, which contains about 4% beryllium, is the principal mineral mined in the rest of the world. Aquamarine, bixbite, emerald, goshenite, heliodor, and morganite are gem forms of the mineral beryl. More information on gem-quality beryl and chrysoberyl can be found in the Gemstones chapter of the U.S. Geological Survey (USGS) Minerals Yearbook, volume I, Metals and Minerals.

Legislation and Government Programs

Defense Production Act.—The Department of Defense awarded a $9 million contract under its Defense Production Act Title III Program to Brush Wellman Inc. [a subsidiary of leading beryllium producer Brush Engineered Materials Inc. (BEM)] for the engineering and design of a new facility to produce beryllium metal. Brush Wellman's beryllium metal production facility in Elmore, OH, had been closed in 2000 as a result of various factors, including equipment obsolescence and the availability of beryllium metal from the NDS. The engineering and design of the new facility was expected to be completed before the end of 2007 and would determine whether the facility would be built in Elmore or near Brush Wellman's beryllium hydroxide plant in Delta, UT. Construction and startup of the new facility was expected to take 2 to 3 years; funding would require additional title III approval (Brush Wellman Inc., 2005).

National Defense Stockpile.—The United States maintained a stockpile of strategic materials for use during a national emergency. As of December 31, 2005, the NDS goal for hot-pressed beryllium metal powder was 45 metric tons (t) (table 2). A goal of 155 t of hot-pressed beryllium metal powder, however, had been proposed in the 2003 National Defense Stockpile Requirements Report to the Congress. The Annual Materials Plan (AMP) for fiscal year 2005, which represented the maximum quantities of beryllium materials that could be sold from October 1, 2004, through September 30, 2005, was unchanged from that of fiscal year 2004 (table 2). The DNSC sold 241 t of beryl ore (10 t of beryllium content) valued at $22,300 in February and 27 t of beryllium metal valued at $4.65 million in September. As of September 30, beryllium inventory sold but not shipped from the NDS included 858 t of beryl ore (34 t of beryllium content), 707 t of beryllium-copper master alloy (BCMA) (28 t of beryllium content), and 28 t of beryllium metal. NDS calendar yearend inventories of beryllium materials are listed in table 2 (U.S. Department of Defense, 2006, p. 5, 10-11, 52, 55-56).

Production

Domestic production and consumption statistics for beryllium-containing ores, as listed in tables 1 and 4, were based on data collected by the USGS by means of two voluntary surveys of U.S. operations. A small number of unidentified producers may have shipped negligible quantities of byproduct beryl, but these have not been included. In 2005, domestic mine shipments were greater than those of 2004.

The United States is one of only three countries known to process beryllium ores and concentrates into beryllium products. Brush Resources Inc. (a subsidiary of BEM) extracted bertrandite from open pit mines in the Topaz-Spor Mountain region of Juab County, UT, and converted the bertrandite, along with imported beryl and beryl from the NDS, into beryllium hydroxide at its operations near Delta. Some of the beryllium hydroxide was shipped to Elmore, where Brush Wellman Inc. converted it into BCMA, metal, or oxide, and some was sold to NGK Insulators, Ltd. of Japan.

Environment

Because of the toxic nature of beryllium, various international, national, and State guidelines and regulations have been established regarding beryllium content in air, water, and

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other media. Industry must maintain careful control over the quantity of beryllium dust, fumes, and mists in the workplace. Control of potential health hazards adds to the final cost of beryllium products (Petkof, 1985, p. 80; Rossman, Preuss, and Powers, 1991, p. 277-281; Kramer, 1998, p. 107-108; Agency for Toxic Substances and Disease Registry, 2002§[1]).

Consumption

U.S. apparent consumption of all beryllium materials, as calculated from mine shipments, net trade, and changes in Government and industry stocks, was estimated to be about 84 t of contained beryllium in 2005, which was 22% higher than the 69 t calculated for 2004. The increased demand in 2005 was met by increases in domestic mine shipments and imports of contained beryllium.

BEM's Beryllium Products unit manufactured products of beryllium metal and two families of metal matrix composites, one made from aluminum and beryllium and the other made from beryllium and beryllium oxide. The products, in the form of rods, sheets, tubes, and a variety of customized shapes, were produced at plants in Elmore and in Fremont, CA. Sales by this unit were 8% higher than those of 2004. The unit completed delivery of the beryllium blanks for the 6.5-meter diameter optical mirror for the National Aeronautics and Space Administration (NASA) James Webb space telescope. During the past 2 years, BEM supplied 19 mirror blanks, each weighing about 550 pounds, 3 smaller mirrors, and structural parts for the telescope. Sales of beryllium products for other defense and Government applications were strong in the early part of 2005 but weakened during the second half of the year, sales to the medical market were less than those of 2004, and sales to the electronics market have been approximately the same for the past 3 years. In 2005, Beryllium Products began to use a newly developed hot isostatic press consolidation process to make near-net-shape aluminum-beryllium metal matrix composite blanks. The blanks were to be machined into parts for a new optical sensing system for the U.S. Army's Apache combat helicopters (Northrop Grumman Corp., 2005; Brush Engineered Materials Inc., 2006a, p. 4, 7, 18; Brush Wellman Inc., undated §).

BEM's Alloy Products unit produced copper- and nickel-base alloy products, the majority of which contained beryllium. Alloy strip products (which were used as connectors, contacts, switches, relays and shielding) and alloy bulk products (including bar, plate, rod, tube, and customized forms) were produced at plants in Elmore and in Shoemakersville, PA. Alloy Product's sales were 3% higher than those of 2004 as a result of increased demand for bulk products. The volume of bulk product shipments increased by 9% owing to increases in demand from the aerospace, appliance, and heavy equipment markets. Some of the increase was from sales of non-beryllium-containing alloys, particularly to the heavy equipment market (Brush Engineered Materials Inc., 2006a, p. 17-18).

Brush Ceramic Products Inc. (a subsidiary of BEM) produced beryllium oxide ceramic products for aerospace, automotive electronics, defense, medical, semiconductor, telecommunications, and wireless applications at its plant in Tucson, AZ. During the year, Brush Ceramics increased its manufacturing capacity by 25%. Sales of beryllium oxide ceramic products declined by 17% compared with those of 2004 as a result of changes in demand from the telecommunications and computer market and reduced orders from consumers that were drawing down high inventories (Brush Engineered Materials Inc., 2006a, p. 20; Brush Ceramic Products Inc., 2005; undated §).

BEM had agreements with the DNSC to purchase beryl ore, BCMA, and beryllium metal from the NDS. In 2005, BEM purchased beryllium materials valued at approximately $7.5 million to be used as raw material input for its operations. The agreements were scheduled to expire in 2007 (Brush Engineered Materials Inc., 2006a, p. 47).

BEM also had a long-term supply arrangement with JSC Ulba Metallurgical Plant (UMP), which was part of Kazakhstan's National Atomic Company Kazatomprom, and its marketing representative RWE NUKEM, Inc., Danbury, CT, to purchase BCMA and beryllium vacuum-cast billet through 2012. In 2005, BEM purchased beryllium-containing materials valued at $7.8 million (Brush Engineered Materials Inc., 2006a, p. 47).

Other domestic producers of beryllium alloy products included Applied Materials Science, Inc., Concord, MA; Freedom Alloys Inc., Royersford, PA; NGK Metals Corp. (a subsidiary of NGK Insulators, Ltd.), Sweetwater, TN; and Olin Corp.'s Brass Division, East Alton, IL. American Beryllia Inc. produced beryllium oxide ceramic products at its plant in Haskell, NJ.

Recycling

Beryllium was recycled primarily from new scrap generated during the manufacture of beryllium-containing components. Detailed data on the quantities of recycled beryllium are not available but may represent as much as 10% of U.S. apparent consumption (Cunningham, 2004§).

Foreign Trade

U.S. foreign trade in beryllium materials, as reported by the U.S. Census Bureau, is summarized in table 3. On a gross weight basis, beryllium exports decreased by 7% compared with those of 2004. Japan was the major recipient of these materials. On a gross weight basis, beryllium imports decreased by 19% in spite of significant increases in imports of beryllium oxide and unwrought beryllium, including powders. Japan and Kazakhstan were the leading suppliers of beryllium materials to the United States. On the basis of estimated contained beryllium, U.S. imports increased by 9% in 2005 compared with those of 2004.

Net import reliance as a percentage of apparent consumption is used to measure the adequacy of current domestic beryllium production to meet U.S. demand. Net import reliance was defined as imports minus exports plus adjustments for Government and industry stock changes. Releases from stocks, including shipments from the NDS, were counted as part of import reliance regardless of whether they were imported or produced in the United States. In 2005, net import reliance as a

[1]References that include a section mark (§) are found in the Internet References Cited section.

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percentage of apparent consumption indicated that the United States was a net exporter of beryllium.

World Industry Structure

In 2005, estimated world beryllium mine production increased by 24% compared with that of 2004 (table 4). The United States accounted for more than 80% of estimated world production.

World Review

China.—Shuikoushan Non-Ferrous Metals Co., Ltd. processed beryllium ores and produced beryllium products in various forms at its 6th Smelting Plant in Songbai Town, Changning City, Hunan Province. The plant had an estimated production capacity of 20 metric tons per year (t/yr) of contained beryllium (McNeil, 2005).

In October, a second Chinese beryllium refinery began production in Fuyun County in northwest Xinjiang Uygur Autonomous Region. It was built by Fuyun Hengsheng Beryllium Industry Co., Ltd. (a joint venture established by Xinjiang Nonferrous Metals Industry Group, Xinjiang Henghe Investment Co., Ltd., and Xinjiang Nonferrous Metals Industry Group Nonferrous Metals Co.) and was designed to produce 100 t/yr of industrial beryllium oxide and 800 t/yr of BCMA. Fuyun County reportedly holds more than 70% of China's beryllium ore reserves, including the Keketuohai No. 3 Mine (Metals Place, 2005§; China Non-Ferrous Metal Import & Export Xinjiang Corp., undated §).

Kazakhstan.—UMP reported that its 2005 beryllium production was eight times that of 1999. A 5-year investment program at UMP was scheduled for completion in 2005. The beryllium program had several components. One part of the program was to use carbothermic reaction technology to increase the production capacity for BCMA by 3,000 t/yr. A second part was to extend the beryllium-copper product range and increase the capacity to produce these products by up to 1,000 t/yr. Other parts of the program focused on introducing new techniques for converting beryllium concentrates using the existing 200-t/yr plant capacity and developing digestion and refining production methods to produce beryllium hydroxide to international standards. UMP's production reportedly was from stockpiled beryllium concentrate imported mainly from Russia. The stockpile, which was built up during the Soviet era, was forecast to be sufficient to support production for about 30 years (Metal Bulletin, 2003; McNeil, 2005; Ulba Metallurgical Plant JSC, 2006§).

Outlook

The United States is expected to remain self-sufficient with respect to most of its beryllium requirements. At yearend 2005, BEM reported proven bertrandite reserves in Juab County of about 5.99 million dry metric tons (6.60 million dry short tons) with an average grade of 0.268% beryllium. This represented about 16,000 t of contained beryllium, which would be sufficient for more than 100 years of operation based on average production levels in recent years. BEM owned approximately 95% of its proven mineral reserves and leased the remainder (Brush Engineered Materials Inc., 2006a, p. 25).

BEM forecast that its sales of beryllium products for aerospace and defense applications could increase during the latter part of 2006. Commercial demand for beryllium products will depend on the performance of the many diverse industries that use them. Industry sectors that use beryllium products include, but are not limited to, aerospace, automotive, computer, defense, electronics, heavy machinery, home appliance, industrial component, instrumentation and control system, medical, nuclear, oil and gas drilling, plastic molding, and telecommunications. BEM stated that demand from such end-use sectors as automotive electronics, industrial components, and telecommunications and computer was strong during the first quarter of 2006 (Brush Engineered Materials Inc., 2006b, p. 15, 21).

World consumption of beryllium was forecast to increase by about 2% per year during the short to medium term. Production and stockpiles were expected to be sufficient to meet demand (McNeil, 2005).

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TABLE 1
SALIENT BERYLLIUM MINERAL STATISTICS

(Metric tons of beryllium content)

	2001	2002	2003	2004	2005
United States, beryllium-containing ores:					
Mine shipments[1]	100	80	85	90	110
Imports for consumption, beryl[2]	19	11	9	--	--
Consumption, reported[3]	170	120	140	130	160
Stocks, December 31:					
Industry[1]	100	90	45	40	35
U.S. Government, beryl:[2, 4]					
Committed	33 r	34	34	60	34
Uncommitted	281	227	227	149	130
Total	315	261	261	209	165
World, production[e, 2]	120	101 r	108	111 r	138

[e]Estimated. [r]Revised. -- Zero.
[1]Data are rounded to the nearest 5 metric tons.
[2]Based on a beryllium content of 4%.
[3]Data are rounded to the nearest 10 metric tons.
[4]Defense National Stockpile Center. Data were converted from gross weights reported in short tons; may not add to totals shown.

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TABLE 2

U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE BERYLLIUM STATISTICS IN 2005[1]

(Metric tons of beryllium content)

Material	Stockpile goal[2]	Disposal authority[3]	Annual Materials Plan[4]	Inventory, December 31		
				Committed[5]	Uncommitted	Total
Beryl ore	--	130	145 [6]	34	130	165
Beryllium-copper master alloy	--	--	44 [6]	3	--	3
Beryllium metal:						
Hot-pressed powder	45	110	NA	NA	156 [7]	NA
Vacuum-cast	--	41	NA	NA	41	NA
Total	45	151	36	28	196	225
Grand total	45	281	225	66	327	393

NA Not available. -- Zero.

[1]Data were converted from gross weights reported in short tons; may not add to totals shown.

[2]Goal effective as of December 28, 2001.

[3]Total quantity of material that can be disposed.

[4]Maximum quantity of material that can be disposed during 12-month period ending September 30, 2005.

[5]Material that has been sold but not yet shipped.

[6]Actual quantity will be limited to remaining inventory.

[7]Held for goal.

Source: Defense National Stockpile Center.

TABLE 3

U.S. FOREIGN TRADE OF BERYLLIUM MATERIALS, BY TYPE[1]

Type and material	2004		2005		Destinations and sources, 2005[2]
	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	
Exports:					
Beryllium, unwrought[3]	153,000	$7,320	151,000	$8,810	Japan, 98%; United Kingdom, 1%; other, 1%.
Beryllium waste and scrap	1,510	51	240	8	Taiwan, 90%; Philippines, 10%.
Beryllium, other[4]	62,500	12,200	50,300	9,760	Canada, 28%; France, 14%; Japan, 12%; Singapore, 11%; Switzerland, 10%; Germany, 8%; Netherlands, 6%; United Kingdom, 4%; Brazil, 2%; other, 5%.
Total	217,000	19,600	201,000	18,600	Japan, 77%; Canada, 7%; France, 3%; Singapore, 3%; Switzerland, 2%; other, 7%.
Imports:					
Beryllium oxide and hydroxide	31,000	351	75,100	466	United Kingdom, 74%; Belgium, 22%; China, 3%; other, 1%.
Beryllium, unwrought[3]	6,270	882	25,600	4,960	Kazakhstan, 100%.
Beryllium waste and scrap	17,200	51	5,820	977	Netherlands, 61%; France, 23%; Germany, 15%.
Beryllium, other[4]	29,700	2,140	16,500	1,930	Kazakhstan, 50%; Japan, 49%; other, 1%.
Beryllium-copper master alloy	511,000	5,630	457,000	3,980	Kazakhstan, 89%; Japan, 7%; China, 3%; other, 1%.
Beryllium-copper plates, sheets, and strip	685,000	5,170	463,000	3,950	Japan, 96%; Germany, 4%.
Total	1,280,000	14,200	1,040,000	16,300	Japan, 47%; Kazakhstan, 42%; United Kingdom, 5%; China, 2%; Germany, 2%; other, 2%.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Data may not add to 100% because of independent rounding.

[3]Includes powders.

[4]Includes articles not elsewhere specified.

Source: U.S. Census Bureau.

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TABLE 4

BERYL: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, gross weight)

Country[3]	2001	2002	2003	2004	2005
Brazil	--	(4) r	(4) r	(4) r	(4)
China	500	500	500	500	500
Madagascar[5]	1 [6]	1	1	1	1
Mozambique	1 [6]	54 [6]	78 [6]	45 r, 6	146 [6]
Portugal	5	5	5	5	5
United States, mine shipments[7]	2,480	1,970	2,100	2,210	2,780
Zambia	7	7	7	7	7
Total	2,990	2,540	2,690 r	2,770 r	3,440

rRevised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 11, 2006.

[3]In addition to the countries listed, Uganda produced beryl. Kazakhstan, Nigeria, and Russia may also have produced beryl, but information is inadequate to make reliable estimates of production. Other nations that produced gemstone beryl may also have produced some industrial beryl.

[4]Less than ½ unit.

[5]Includes ornamental and industrial products.

[6]Reported figure.

[7]Includes bertrandite ore, calculated as equivalent to beryl containing 11% beryllium oxide.

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BISMUTH

By James F. Carlin, Jr.

Domestic survey data and tables were prepared by Robin C. Kaiser, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

Bismuth was last produced domestically, as a byproduct of lead refining, at a Nebraska refinery that closed in 1997. The last stocks of bismuth held in the National Defense Stockpile were sold that same year. In 2005, all primary bismuth consumed in the United States was imported. Only a small amount of bismuth was obtained by recycling old scrap. The leading foreign producers of refined bismuth in 2005 were Belgium, China, Japan, Mexico, and Peru. Belgium had no mine production, and its sole bismuth producer refined metal from anode slimes, concentrates, and smelter residues and flue dust, all of foreign origin.

Bismuth consumption in the United States was estimated to be 2,340 metric tons (t), a decrease of 3% compared with that of 2004. As a result of an ongoing U.S. Geological Survey (USGS) analysis and evaluation of the bismuth market that began in 2003, end-use patterns for 2003, 2004, and 2005 contain different assumptions than in previous years. The estimated domestic consumption of bismuth for 2005 was about 49% for metallurgical additives for castings and galvanizing; 29% for bismuth alloys, fusible alloys, solder, and ammunition; 21% for chemical and pharmaceutical uses; and 1% for research and other uses (table 2).

In recent years, new uses for bismuth have been developed as a nontoxic substitute for lead. These include the use of bismuth in shot for water fowl hunting, lubricating greases, pigments, and solders.

The average annual dealer price for bismuth increased to $3.91 per pound, an increase of 17% more than that of 2004. Strong world mine and refinery output especially from China helped to moderate the price increase in light of continuing steady to strong world demand.

The estimated value of bismuth consumed domestically was about $20 million in 2005. That represents an increase of 13% compared with the value in 2004.

Legislation and Government Programs

The Safe Drinking Water Act Amendments of 1996 (Public Law 104-182) banned lead from all fixtures, fluxes, pipes, and solders used for the installation or repair of facilities providing potable drinking water since 1998. The ban prompted a conversion to plumbing alloys that contain bismuth rather than lead. Increased use of plastic pipe, however, has kept the use of bismuth-alloyed brass from growing more rapidly in plumbing applications.

Production

Domestic production of primary refined bismuth ceased in 1997. Some domestic firms continued to recover secondary bismuth from fusible alloy scrap in 2005, but secondary production data were not available. Secondary production was estimated to be less than 5% of domestic supply during the year.

Consumption

The USGS surveys domestic bismuth consumption annually. The amount used by nonrespondents is estimated based on reports from prior years or on information from other sources. Accordingly, estimated bismuth consumption was about 2,340 t in 2005, a 3% decline from that of 2004 (table 1). The USGS is continuing to reevaluate the domestic bismuth market and canvassed companies; therefore, the use patterns for 2003, 2004, and 2005 contain different assumptions than those in previous years.

Consumption of bismuth in chemical uses (chemicals, cosmetics, and pharmaceuticals) in 2005 decreased by 15% compared with use in 2004. The leading use, metallurgical additives, experienced a 4% increase in consumption in 2005 compared with that in 2004. The alloys category of use registered a 3% decline in tonnage compared with that of 2004.

Although it has the crystal structure of a semimetal, bismuth is often considered a metal. This crystal structure, along with several of its other salient properties, makes it an ideal substitute for lead in extreme-pressure additives. These unique properties include expansion on solidification, the widest range between melting and boiling points among all metals, and the lowest thermal and heat conductivity. Bismuth is the most diamagnetic of all metals, the least toxic, and has the lowest absorption for neutrons; bismuth is also characterized as "soft" like lead.

Bismuth pharmaceuticals include the well-known bismuth salicylate (the active ingredient in the over-the-counter stomach remedies) and other bismuth medicinal compounds used to treat burns, intestinal disorders, and stomach ulcers in humans and animals. Bismuth nitrate is the initial material used for the production of most bismuth compounds. Other applications of bismuth chemicals and compounds include uses in superconductors and pearlescent pigments for cosmetics and paints.

Bismuth metal is used primarily as a major constituent of various alloys and as a metallurgical additive (table 2). One class of bismuth alloys consists of fusible (low-melting-point, as low as 20° C) alloys—combinations of bismuth with other metals, such as antimony, cadmium, gallium, indium, lead, and tin. Applications for those alloys include fuel tank safety plugs, holders for optical lens grinding, and other articles for machining or grinding, solders, and fire sprinkler triggering mechanisms.

In addition to lead-free solder noted above, bismuth has long been a substitute for the lead added to certain steel products to provide greater machinability. A major domestic steel producer began to use a bismuth-containing substitute for the leaded alloy about 25 years ago. Although bismuth has been successfully

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used in replacing lead in various applications, it has been challenged as a lead substitute by tin and tungsten (Cusack, 1999). Bismuth is also added in small amounts to aluminum (along with lead) and copper alloys to improve machinability. Also, it is added to malleable iron graphite flakes. These uses constitute the traditional metallurgical additives category.

Prices

In 2005, the average dealer price for bismuth rose to $3.91 per pound, an increase of 17% from the average price of $3.35 per pound in 2004. The average annual price has experienced a steady and substantial rise starting in 2003.

The weekly price started 2005 at $3.40 to $3.70 per pound, then rose steadily through the third quarter to end at $4.40 per pound. Continued rises in the fourth quarter took the price to $4.65 per pound by yearend.

Trade

U.S. bismuth exports by weight rose about 31% from those of 2004. By value, the 2005 exports were almost twice those of 2004. While bismuth prices rose moderately for the year, the almost doubling in the value of exports was because of shifts in the types of value-added bismuth products exported. Measured by weight, notable export increases were recorded in 2005 by Belgium and Canada, while substantial decreases were experienced by the Dominican Republic, Japan, and Mexico (table 3).

Total U.S. bismuth imports increased 28% by weight and 41% by value in 2005 compared with the prior year's figures (table 4). Bismuth imports were 18 times greater, by weight, than bismuth exports. The leading import source for the United States was Belgium, which supplied 42% of imports. Considerable increases in imports were observed for Belgium, China, and the United Kingdom. Notable decreases in imports were recorded for Germany, Hong Kong, and Peru.

World Review

In much of the world, bismuth is produced as a byproduct of smelting lead ores. In China, it is also a byproduct of fluorspar, tin, and tungsten ore processing. In Bolivia, the Tasna Mine, the only mine that produces bismuth from bismuth ore, has been on standby since the mid-1990s awaiting a sufficient rise in the metal price. There are several other deposit types that may be developed in the near future that would have bismuth as a coproduct.

World refining production of bismuth increased by 20% in 2005 (table 5). China was the world's leading producer of refined bismuth with 71% of the world total, followed by Mexico with 8%, and Belgium with 7%.

Belgium.—Sidech S.A. (Tilly, Belgium), a leading refiner of bismuth and other minor metals such as indium, selenium, and tellurium, announced that it had been approved for membership in the Minor Metals Trade Association (MMTA). Siddech's inclusion into the MMTA brings MMTA's total membership to 70 firms (Metal Bulletin, 2005b).

Canada.—Fortune Minerals Ltd. in London, Ontario, Canada, continued to report progress at its NICO gold-cobalt-bismuth deposit, located 160 kilometers northwest of the city of Yellowknife, Northwest Territories. Fortune announced that it had entered into an agreement with Mindecom Industrial Contractors Ltd. to purchase the mill and certain other buildings from the Golden Giant Mine at Hemlo, Ontario, currently owned by Newmont Canada Ltd., for $2.8 million. The Hemlo facilities would be purchased for use at Fortune's 81%-owned NICO deposit. The deposit was expected to be mined by a combination of underground and open pit methods, and the ore would be processed in a 3,000-metric-ton-per-day mill and hydrometallurgical plant to produce bismuth concentrate, cobalt cathode, and gold dore. The deposit was estimated to contain about 34,500 t (76.5 million pounds) of bismuth (Fortune Minerals Ltd., 2005).

China.—Reports from China, the world's leading bismuth-producing country, indicated that raw materials shortages continued to hamper bismuth smelters. Ore supply has become increasingly tight as existing mines are exhausted, and new discoveries are lagging. China's leading bismuth producer, Hunan Shizhuyuan Nonferrous Metals Co., expected its bismuth production to be 10% lower in 2005 than in 2004 and another 20% lower in 2006 than in 2005. China's refined bismuth production is about 8,500 metric tons per year (t/yr) but may well decline in coming years owing to mine depletion and falling bismuth content in ores. While large producers are facing production cuts, some smaller privately owned smelters are struggling to survive. Yongxin Daxin Nonferrous Metals Co., a private smelter in Chenzhou, Hunan Province, may close at yearend 2005 because of difficulties in sourcing raw materials. Bismuth-rich mines in China have largely been exhausted by extensive mining, and ores that are available domestically and from overseas, such as Africa and South America, are often too expensive (Metal Bulletin, 2005a).

A 300-t/yr bismuth production facility began operation in Chifeng City, Inner Mongolia, in June. The plant was funded by Yunnan Copper Bismuth Co., a joint venture between Yunnan Copper Co. and two large-scale bismuth producers in Chenzhou, Hunan Province. Another facility located in the industrial zone of Yunnan Copper Co. in the Dongchuan District, was expected to start production in late 2005. Upon completion of the project, the combined capacity of the three production facilities would reach 1,000 t/yr (Beijing Antaike Information Development Co., Ltd., 2005§[1]).

Mongolia.—Canadian-based exploration company QGX Ltd. acquired a 100% interest in the Undur Tsagaan property in Khenti Province in northeast Mongolia. The prospect was thought to be the largest known occurrence of molybdenum and tungsten in Mongolia. Earlier (1979-82) drilling and exploration work by Russian and Mongolian exploration teams estimated resources of 141 million metric tons (Mt) containing 0.03% Be and 0.08% Bi, and resources of 60 Mt containing 0.11% WO_3, 0.03% Mo, 0.03% Be and 0.01% Bi (QGX Ltd., 2005).

Vietnam.—Tiberon Minerals Ltd. in Toronto, Ontario, Canada, announced that it increased its expenditures in 2005 on

[1]A reference that includes a section mark (§) is found in the Internet Reference Cited section.

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development of its Nui Phao project in Vietnam. The increase in development and exploration expenditures was owing to the advanced stage of the project and the completion of the final feasibility study. Tiberon's primary interest in the Nui Phao property is fluorspar and tungsten, but there are also promising quantities of bismuth. The latest study concluded that open pit mining will probably produce 3.5 Mt of acid-grade fluorspar concentrate, 76,000 t of tungsten trioxide, and 32,000 t of bismuth during a 16-year mine life. Tiberon holds a 77% interest in the Nui Phao project. Tiberon and its two Vietnamese partners, Thai Nguyen Mineral Co. (15% interest) and Export-Import Investment Company Thai Nguyen or "Intraco" (8% interest) formed the Nui Phao Mining Joint Venture Co. Ltd. to develop and operate the mine (Tiberon Minerals Ltd., 2006).

Outlook

Worldwide bismuth demand appeared to be increasing at about 3% to 5% per year. Demand for bismuth in the steel sector, although relatively minor compared with other use sectors, appeared to be increasing. World consumption in the chemical field seemed to be rising, especially in Japan, as bismuth there was starting to replace lead in pigments.

Commercial and research organizations in Europe, Japan, and North America agreed to a framework to eliminate lead from solders in manufacturing. This agreement would tend to increase the demand for bismuth during the next several years. Many Japanese manufacturers are using lead-free solder in some or all of their soldering applications, and studies on how best to develop lead-free solders were being performed independently by the European Union, Japan, the Republic of Korea, and the United States. Although world lead consumption was expected to be reduced by only 0.8%, world bismuth consumption will probably increase by about 25% with a move to lead-free solders.

A significant near-term increase in supplies of lead byproduct bismuth was unlikely because total world production of lead was expected to remain relatively stable, and an increasing portion of lead demand was expected to be met by recycling. A global shortage of bismuth, however, was not anticipated.

In China, where bismuth is a byproduct of fluorspar, lead, tin, and tungsten and processing, new technologies applied to this resource have increased world bismuth reserves. Therefore, despite possible large increases in world demand, Chinese supplies can be expected to help keep the bismuth market stable.

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TABLE 1
SALIENT BISMUTH STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Consumption	metric tons	2,200	2,320	2,120	2,420	2,340
Exports[2]	do.	541	131	108	109	142
Imports for consumption	do.	2,220	1,930	2,320	1,980	2,530
Price, average, domestic dealer	dollars per pound	3.74	3.14	2.87	3.35 r	3.91
Stocks, December 31, consumer	metric tons	95	111	279	134 r	136
World:						
Mine production, metal content[3]	do.	5,100 r	4,700 r	5,100 r	5,600 r	5,500 e
Refinery production[4]	do.	5,800 r	6,700 r	8,700 e, r	10,000 e, r	12,000 e

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits.

[2]Comprises bismuth metal and the bismuth content of alloys and waste and scrap.

[3]Excludes the United States.

[4]Excludes Canada.

TABLE 2
BISMUTH METAL CONSUMED IN THE UNITED STATES, BY USE[1]

(Metric tons)

Use	2004	2005
Chemicals[2]	584	498
Bismuth alloys	703	685
Metallurgical additives	1,110	1,150
Other	22	14
Total	2,420	2,340

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes industrial and laboratory chemicals, cosmetics, and pharmaceuticals.

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TABLE 3
U.S. EXPORTS OF BISMUTH METAL, ALLOYS, AND WASTE AND SCRAP, BY COUNTRY[1]

Country	2004 Quantity (kilograms, metal content)	2004 Value (thousands)	2005 Quantity (kilograms, metal content)	2005 Value (thousands)
Argentina	--	--	240	$57
Belgium	2,720	$67	17,000	69
Brazil	1,140	156	4,260	112
Canada	46,000	812	70,100	870
Chile	--	--	1,560	34
China	99	3	35	6
Colombia	--	--	39	7
Dominica	53	9	--	--
Dominican Republic	11,100	664	5,420	219
France	--	--	10,100	2,300
Germany	1	3	--	--
Guatemala	229	4	--	--
Hong Kong	360	70	234	43
Israel	--	--	50	12
India	--	--	2,000	23
Ireland	--	--	618	8
Italy	113	18	--	--
Japan	5,320	102	2,100	84
Korea, Republic of	75	5	293	15
Malaysia	--	--	11	3
Mexico	28,500	488	17,400	843
Russia	2,090	33	--	--
Singapore	59	20	160	5
South Africa	--	--	98	6
Spain	--	--	1,000	10
Taiwan	--	--	49	8
United Kingdom	10,700	48	8,840	26
Total	109,000	2,500	142,000	4,760

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF METALLIC BISMUTH, BY COUNTRY[1]

Country	2004 Quantity (kilograms)	2004 Value (thousands)	2005 Quantity (kilograms)	2005 Value (thousands)
Bahamas, The	1,910	$12	2,620	$25
Belgium	793,000	5,740	1,050,000	8,360
Canada	8,760	664	7,370	72
China	169,000	1,280	667,000	5,490
Germany	162,000	809	18,500	199
Hong Kong	77,100	722	--	--
Italy	--	--	106	25
Mexico	495,000	3,310	480,000	3,750
Netherlands	232	25	4	2
Peru	39,800	298	--	--
Russia	52	12	--	--
Spain	500	6	700	10
Switzerland	--	--	1	4
United Kingdom	237,000	1,640	304,000	2,550
Total	1,980,000	14,500	2,530,000	20,500

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 5
BISMUTH: WORLD MINE AND REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	Mine 2001	Mine 2002	Mine 2003[e]	Mine 2004[e]	Mine 2005[e]	Refinery 2001	Refinery 2002	Refinery 2003[e]	Refinery 2004[e]	Refinery 2005[e]
Belgium[e]	--	--	--	--	--	700	1,000	1,000	800	800
Bolivia	8	20	72[3]	62[r, 3]	60	66	88	88	33[r, 3]	30
Bulgaria[e]	40	40	40	40	40	40	40	40	35[r]	35
Canada[4]	258	189	145	145	190	250[e]	250[e]	250	250	250
China[e]	2,000[r]	2,000[r]	2,500[r]	3,000[r]	3,000	2,000[r]	3,000[r]	5,000[r]	7,000[r]	8,500
Italy[e]	--	--	--	--	--	5	5	5	5	5
Japan[e, 5]	28	24	26[r]	23[r]	27	551	474	513[r]	522[r]	530
Kazakhstan[e]	252	161	150	150	140	130	130	130	130	120
Mexico	1,390[6]	1,126	1,064[3]	1,064[r, 3]	970	1,390	1,126	1,064[3]	1,064[r, 3]	970
Peru[e]	1,000	1,000	1,000	1,000	1,000	640[3]	568[3]	600[r]	600	600
Romania[e]	40	40	40	40	40	35	35	35	35	35
Russia[e]	50	50	50	50	50	10	10	10	10	10
Serbia and Montenegro[e]	2	2	1	--	--	--	--	--	--	--
Tajikistan	5	--	--	--	--	--	--	--	--	--
United States	--[r]	--[r]	--[r]	--[r]	--	--	--	--	--	--
Total[7]	5,100[r]	4,700[r]	5,100[r]	5,600[r]	5,500	5,800[r]	6,700[r]	8,700 r	10,000[r]	12,000

[e]Estimated. [r]Revised. -- Zero.

[1]Estimated data are rounded to no more than three significant digits.

[2]Table includes data available through April 4, 2006. Bismuth is produced primarily as a byproduct of other metals, mainly lead and tungsten.

[3]Reported figure.

[4]Figures listed under mine output are the metal content of concentrates produced, according to Natural Resources Canada, 2004-05.

[5]Mine output figures have been estimated to be 5% of reported metal output figures.

[6]Refined metal plus bismuth content of impure smelter products.

[7]World totals are rounded to no more than two significant digits.

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BORON

By Phyllis A. Lyday

Domestic survey data and tables were prepared by Imogene P. Bynum, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Boron, a nonmetal, has atomic number 5 and is in periodic group 13. Elemental boron is a dark brown powder in the amorphous form and a yellowish-brown hard, brittle solid in the monoclinic crystalline form. Elemental boron is marketed in grades from 90% to 99% purity. Borax is a white crystalline substance chemically known as sodium tetraborate decahydrate and found in nature as the mineral tincal. Boric acid is a white, colorless crystalline solid sold in technical national formulary and special quality grades as granules or powder. Boron oxide is a colorless hard, brittle, solid resembling glass that is ground and marketed most often under the name anhydrous boric acid.

Boron ore produced domestically during 2005 totaled 1.15 million metric tons (Mt) valued at $713 million (table 1). The boron oxide (B_2O_3) content was 612,000 metric tons (t). The most common minerals of commercial importance in the United States were colemanite, kernite, tincal, and ulexite (table 2). Boron compounds and minerals were produced by surface and underground mining and from brine. U.S. consumption of minerals and compounds reported in boron oxide content (table 3) was significantly more than reported for previous years and was withheld while verifying the reported data. Boron products are priced and sold based on the boric oxide content, which varies by ore and compound, and on the absence or presence of sodium and calcium (table 4). Boron compounds exported by producers were boric acid (183,000 t) and sodium borate (308,000 t) (tables 1, 5). Boron imports consisted primarily of borax, boric acid, colemanite, and ulexite (tables 1, 5-6). Turkey and the United States were the world's leading producers of boron minerals (table 7).

Legislation and Government Programs

Searles Valley Minerals, Inc. (SVM) (a subsidiary of Sun Pertners, Ltd., Boca Raton, FL) is one of 15 trade associations and business groups taking part in Climate VISION (Voluntary Innovative Sector Initiatives: Opportunities Now), a presidential public-private partnership established in 2003. The associations' goal was to reduce carbon emission by 4.2% per metric ton of product produced by 2012. The Trona plant has already exceeded that goal. The cost of the project that included insulating equipment and installing energy efficient burners in the driers has rewarded SVM by increased efficiency and energy savings (Saholt, 2005).

In the process of setting standards that will determine if borate material may be used, and if so, the amount, the Consumer Product Safety Commission met to determine a flammability standard for upholstered furniture. The Commission also considered a final rule under the Flammable Fabrics Act for mattress flammability (open flame) (Consumer Product Safety Commission, 2006). Currently, only California has a standard to make residential mattresses resistant to open flames. Between 1995 and 1999, 440 deaths and 2,230 injuries as well as $274 million in property damage were a result of residential fires. The rule would create one national flammability standard that could reduce the number of deaths by 80% (Skrzycki, 2005).

Production

More than 200 minerals contain boric oxide, but only a few were of commercial importance (table 2). Four minerals make up almost 90% of the borates used by industry worldwide; they are the sodium borates borax and kernite, calcium borate colemanite, and sodium-calcium borate ulexite. These minerals were extracted primarily in California and Turkey and to a lesser extent in Argentina, Bolivia, Chile, China, and Peru.

Domestic data for boron were derived by the U.S. Geological Survey from a voluntary survey of four U.S. operations. The majority of boron production continued to be from Kern County, CA, with the balance from San Bernardino and Inyo Counties, CA. All four operations to which a survey request was sent responded, representing 100% of the total boron produced and consumed (tables 1, 3).

American Borate Co. (ABC) mined small amounts of colemanite and ulexite-probertite underground at the Billie Mine in Death Valley, CA. The ore was transported to Lathrop Well, NV, for processing. Storage and grinding facilities were at Dunn, CA. During 2005, reclamation of the mine began as ABC lost its prime customer.

Fort Cady Minerals Corp. used an in situ process near Hector, CA, to produce a product that contained 48% boron oxide. During 2005, the plant was idle, but the product in storage was being marketed. The company had hired consultants to assess the market for boron oxide derivatives and whether additional downstream plants should be built to market boron compounds. An assessment was ongoing during 2005.

SVM continued production of borax and boric acid from brines pumped from Searles Lake.

U.S. Borax, Inc. (a wholly owned subsidiary of London, United Kingdom-based Rio Tinto plc) mined borate ores at Boron, CA, by open pit methods and transported the ores to a storage area by trucks. The property is the world's largest producer of refined borate products (Mattern, 2005). The ore was processed into sodium borate or boric acid products in the refinery complex adjacent to the mine. An onsite plant also produced anhydrous sodium borate and boric oxide. Refinery products were shipped by railcar or truck to North American customers or to the U.S. Borax Wilmington, CA, facility at the Port of Los Angeles for international distribution. In addition to its refinery and shipping terminal in Wilmington, U.S. Borax has its global headquarters in Valencia, CA, and its Owens Lake,

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CA, trona mine supplies raw material to the Boron, CA, refinery. U.S. Borax's Owens Lake operation allowed the company to ensure control of the trona supply used in the borate refining process. Trona provided a cost-effective source of carbonates, which helped reduce scaling in the processing equipment. Multiyear labor agreements that will provide additional operational flexibility and efficiency were negotiated at U.S. Borax's U.S. operations.

Consumption

Agriculture.—Boron is 1 of 16 nutrients essential to all plants. Boron is necessary in controlling flowering, fruit development, germination, plant reproduction, and pollen production. Domestic consumption was estimated at 2% in fertilizer usage. Boron is essential to plant growth and can be applied as a spray and incorporated in fertilizer, herbicides, and irrigation water. Boron fertilizers can quadruple corn yields and increase cotton yields by more than 227 kilograms per acre (500 pounds per acre). Boron deficiencies in crops are found primarily in soils low in organic matter and in acid, sandy soils in humid regions. Boron applied in May and June during early growth can be combined with calcium. For early season apples, boron can be applied post-harvest to provide adequate nutrition when buds begin to develop for blooming the next growing season. In the crop year ending June 30, 2005, 12,900 t (14,200 short tons) of boron micronutrients was applied on crops compared with 9,480 t (10,400 short tons) in crop year 2004. The leading consuming U.S. region in 2004 and 2005 was the Pacific, which used approximately 3,950 t (4,360 short tons) in both years (Terry and Kirby, 2004, p. 37; 2005, p. 37).

Fire Retardants.—Zinc borate was used in plastics as a multifunctional boron-base fire retardant with applications in a variety of plastics and rubber compounds. Depending on the polymer used and fire standards to be met, zinc bromate can replace other fire-retardant additives, such as antimony oxide. Zinc bromate was normally used in conjunction with aluminum trihydrate, magnesium hydroxide, or a silicon polymer. Boric acid is used in cellulose insulation, in cotton mattresses, and in wood as a fire retardant.

Glass.—Glass is a generic term for a fused-silica material with many different compositions. For most scientific glassware, low-expansion borosilicate glass is used, because it is inert to most chemicals and can withstand changes in temperature. The major glass sectors are container, flat, fiber, and specialty. The glass industry remained the leading domestic market for boron production, as in previous years. Boron oxide generally reduces melting temperatures and helps with the fiberizing process by lowering viscosity, controlling thermal expansion, inhibits devitrification, increases durability and chemical resistance, and reduces susceptibility to mechanical and thermal shock. Various brands of borosilicate glass are Corning Inc.'s Pyrex®, Kimbel Glass Co.'s Kimax, and Schott North America Inc.'s Duran®.

Reinforcing fibers are produced by drawing fibers from orifices in a platinum bushing, spraying the fibers with a sizing and winding onto a spool. Fiber glass for reinforced plastics accounted for most production. The fibers are mixed with thermosetting materials such as epoxy, polyester, and vinyl esters to form composites. In the United States the following companies produce fiberglass: CertainTeed Corp., Owens-Corning Fibreglas Corp., PPG Industries, and Saint Gobain Owens.

Glass Fiber Inc. of Chino, CA, received a permit to operate a fireproof insulation required for all commercial air craft beginning in 2007. The plant will recycle glass to produce the insulation. The company has contacts with European Airbus and American Boeing companies to supply new aircraft and maintenance, repair, and overhaul for replacement blankets (Kitching, 2004§[1]).

Borosilicate glass, with a loading of high level nuclear waste of up to 30%, reduced the melting temperature without sacrifice in leach ability. Emphasis on cleanup of defense sites including France, Germany, Japan, the United Kingdom, and the United States uses glass technology to immobilize contaminated materials and sites. The glass encased waste is encased in a nickel-base alloy that provides protective barriers against chemical and physical stresses during disposal, interim storage, and transportation.

High boron frits mature rapidly, improve the speed at which smooth, even glaze surfaces develop, and provide good bases for coloring oxides. For the glass surfaces of ceramics and enamels boric oxide acts as a network former and flux.

Soaps and Detergents.—Sodium percarbonate can substitute for sodium perborate in laundry products.

Other.—Boron oxide is incorporated into cellulose materials, borates change the oxidation reactions and promote the formation of 'char' thereby inhibiting combustions. Boric acid is effective in reducing the flammability of cellulose insulation, cotton batting used in mattresses, and wood composites. Borates are a part of the starch adhesive formulation for corrugated paper and paperboard and peptizing agent in the manufacture of casein-base and dextrin-base adhesive.

Boron fiber is a wire of tungsten with elemental boron deposited during a reaction of boron trichloride and hydrogen gas at 800° to 2000° C. Boron fiber is so stiff and strong that it has been used to patch across the fuselage of jet fighter aircraft to hold the wings on. The primary structural member of the B-1 bomber is a single lengthwise beam constructed of boron fiber construction.

Borazine and polyborazylene can be used as precursor's chemicals to boron nitride coatings and composites.

Boric acid has applications in cosmetics, pharmaceuticals, and toiletries. Borates are also added to lubricants, brake fluids, metalworking fluids, water treatment chemicals, and fuel additives. Boron oxide inhibits corrosion.

Transportation

The Trona Railway, connected to the Southern Pacific Railroad between Trona and Searles Stations in California, provided a dedicated line with access to the national rail systems for the borate and soda ash markets.

Almost all U.S. Borax bulk products were shipped in North America by rail. The Boron Mine at Boron is served solely by

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the Burlington Northern Santa Fe Railroad. In order to connect to another rail line, a transload or transfer point was set up in Cantil, CA, which is served by the Union Pacific Railroad. Trucks of product from Boron are driven to Cantil, about 64 kilometers (km) (40 miles) northwest of Boron, CA, and loaded into dedicated railcars to be shipped to customers.

Cross-country rail shipments are more cost effective in the United States than the use of ocean transportation. Prices for rail haulage depended on a number of factors including the ability of customers to load and unload efficiently, the ability to use whole unit trains, and the ability to supply their own railcars. The recent increase in fuel prices is another factor affecting cost with carriers passing on surcharges to customers.

Ocean transport of U.S. Borax products was from the Port of Wilmington, where the company had a privately owned berth in the harbor. Products destined for Europe were shipped from the bulk terminal in Wilmington to a company-owned facility in the Port of Rotterdam, Netherlands, to company facilities in Spain, and to contracted warehouses. Borax Group also maintains secondary stock points that include Austria, Germany, Norway, the Republic of Korea, Taiwan, and Ukraine. The most centrally located U.S. Borax port location in Europe was Antwerp, Belgium. The industrial minerals market in Europe was characterized by high volumes of imported materials, mostly forwarded through the industrialized areas of Belgium, France, Germany, and the Netherlands for destinations in Central Europe, such as Austria, the Czech Republic, and Slovenia. A decision to import borates was based on the geographic location, the range of service needed, and prices.

U.S. Borax used barges to ship borates from Rotterdam, Netherlands, to customers in Belgium, Eastern Europe, France, Germany, and countries even farther away. Barges were the most efficient and reliable method of transporting goods in Europe because most of the large industrial areas could be reached on waterways that link parts of the North, Baltic, Black, and Mediterranean Seas and the Atlantic Ocean.

Prices

Prices of boron minerals and compounds produced in Chile, Turkey, and the United States are listed in table 4.

World Review

Argentina.—In 2005, Argentina was the leading producer of boron minerals in South America. Borax Argentina S.A. (a subsidiary of Rio Tinto plc) was the country's leading producer of borates and exported to the United States (tables 6-7). Borax Argentina mined borates at four deposits—Tincalayu and Sijes in Salta Province, at more than 4,270 meters (m) (14,000 feet) above sea level, and two dry lake beds, Salars Cauchari and Diabillo in Jujuy Province at 3,370 m. Yacimiento de Boroato El Porvenir at the Salar Cauchari produces ulexite that grades 37% boron oxide. The Tincalayu Mine, originally developed in 1976, was Argentina's largest open pit operation and measured 1.5 km long, 500 m wide, and 100 m deep. Commercial borates mined were colemanite, hydroborocite, kernite, tincal, and ulexite. The clay overburden averages 50 m and typically overlies 30 to 40 m of ore. Tailings from the company's ulexite concentration operation were used as feedstock to supply 8,000 t of boric acid production.

In 1998, Minera Santa Rita S.R.L. bought the boric acid manufacturing plant in Campo Quijano, and doubled the production in 1999. In 2005, boric acid sales were reported at 27,657 kg. The company produced derivative products for specific applications such as granular deca- and penta-hydrate borax, technical grade boric acid power, and various grades and sizes of the natural boron minerals. The products are sold in 25-kilogram and 1-ton bags. The ore was mined from Salar de Pozuelos at Mina San Mateo, Salar de Pastos Grandes at Mina San Cayetona, and Salar de Ratones at Mina Isla. The company reported a reserve of more than 1 Mt of minerals (Minera Santa Rita S.R.L., 2006§).

Other borate producers in the Province of Juyuy included Processadora de Boratos Argentina S.A. (owned by Ferro Corp. and Canadian JEM Resources & Engineering, Inc.), which produced borates from 2-m-thick layers of tincal and ulexite interbedded with clay and lenses of inyoite; Cia Minera Gavenda S.A., which produced borates at the La Inundada Mine at Salar Cauchari from layers of ulexite up to 1-m thick that grade between 11% and 35% B_2O_3; and Triboro S.A., which operated the Irene Mine where ulexite was mined that contained between 11% and 35% B_2O_3. Other producers in Argentina were Coop. de Borateros, Moncholi y Guijarro, Ramiro Matinez, and Viento Blanco S.R.L.

Manufacturas Los Andes S.A. is a newly formed company, that produces boric acid located in the town of Olacapato. The mine and plant was located in the Andes Mountain Range at an elevation of 3,700 m, near the border with Chile. Ulexite from Salar de Diabillo is mined and produced into 99.5% pure boric acid (Gruposaenz, 2006§).

Bolivia.—Quiborax was preparing a claim about the expropriation of its mining concessions in Salar de Uyuni for the World Bank's international center for the settlement of investment disputes. Quiborax's subsidiary Non Metallic Minerals (NMM) extracted ulexite from Salar de Uyuni in southwest Potosi until Bolivia's mining and hydrocarbons ministry rescinded the concessions in June 2004. Quiborax had to wait six months before taking action. NMM exported 76,280 Mt of ulexite to Chile between 2001 and August 2004 (Industrial Minerals, 2005).

India.—A 10.75-crore enriched boric acid plant was expected to be built in Khamman district by 2009. The plant is being promoted by the Department of Atomic Energy (Business Standard, 2006§).

Serbia.—The mineral rights to the Piskanja boron property were awarded to Rio Tinto plc in fall 2005, prompting legal action by Erin Ventures Inc., Kelowna, Canada, based on a prior joint venture contract with Elektroprevreda-Serbia, the Serbian government's wholly owned national power company (Erin Ventures, 2005§). Piskanja is the larger of two boron deposits in the Jarando Basin, an area in which the joint venture, Ras-Borati LTD., had been active. The primary mineralization is colemanite and ulexite. Proven and probable reserves are estimated at 7 Mt with an average grade of 39% boron oxide, according to the Geologic and Mining Institute in Belgrade. The

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other deposit, the Pobrdjski Potok property on the north side of the basin, is thought to have resources of only 140,000 t with an average grade of 37% boron oxide (Erin Ventures, Inc., 2001§).

Turkey.—Turkey was the leading producer of boron ore in the world and was expanding plant capacity to produce boron compounds. Turkey has an estimated 29.1% share of the worldwide borate market. Annual boric acid production capacity was 100,000 metric tons per year (t/yr) at Emet, a new plant, 85,000 t/yr at Bandirma, and 35,000 t/yr at Kirka. A 48,000-t/yr borax pentahydrate plant, a 65,000-t/yr borax decahydrate plant, and a 10,000-t/yr anhydrous borax plant were located at Kirka. Other capacities included a 22,000-t/yr sodium perborate tetrahydrate plant and a 9,000-t/yr sodium perborate monohydrate plant at Bandirma. Borate mine capacity was available at Bigadic (180,000 t/yr of colemanite), Emet (660,000 t/yr of colemanite), and Mustafa Kemalpasa (480,000 t/yr of colemanite and ulexite). In addition, 800,000 t/yr of tincal was produced at Kirka.

Current Research and Technology

An osmium diboride compound was prepared by solid-state synthesis procedures to prepare a material that was close in hardness to a diamond. Hard materials are widely used to provide durable and wear-resistant coating for drilling and cutting tools and in other applications (Chemical & Engineering News, 2005).

Millennium Cell Inc.'s HOD systems generate hydrogen from sodium borohydride, which is a derivative of borax. Sodium borohydride fuel solutions are nonflammable, high in energy density, and easily distributed for civilian and military users. The restrictions of battery capacity and the inefficiency of power consumption have become major factors limiting the effective use of mobile electronic equipment. The Air Force Research Laboratory awarded a $2.6 million contract in spring 2005 to Protonex Technology Corp. and Millennium Cell Inc. to further the development of a lighter, innovative power solution. The contract addresses the need to replace the BA 5590, the lithium-sulfur dioxide battery used for military communications and other needs with the Protonex proton exchange membrane (PEM) fuel cell with the Millennium Cell's Hydrogen on Demand® fuel in an integrated, 30-watt HOD/PEM system (Gerber, 2005).

Magnesium diboride conducts electricity without resistance at temperatures approaching 40 K and can be cooled by liquid hydrogen or liquid neon or by cheap, closed-cycle refrigeration units that can be cooled below 20 K. Wires were prepared by exposing boron filaments to magnesium vapor. Possible applications include superconducting magnets and powerlines (Canfield and Sergey, 2005).

Three boron compounds exist in the titanium-boron system: titanium boride (TiB), titanium diboride (TiB_2), and trititanium tetraboride (Ti_3B_4) at boron concentrations of about 18%, 22%, and 30% by weight. Because TiB forms as long, pure single-crystal whiskers, it is useful for reinforcing titanium. Large increases in strength can be obtained with a relatively small amount of reinforcement. Its use is also attractive because there is no intermediate phase between titanium and TiB and the formation of TiB requires a lower amount of boron compared to TiB_2. Possible uses include replacement of high-strength steels, saving 40% of the weight of the structure and providing significant increases in corrosion resistance, oxidation, and wear. Present applications included automobile components and golf club heads (Ravi Chandran, Panda, and Sahay, 2004).

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TABLE 1

SALIENT STATISTICS OF BORON MINERALS AND COMPOUNDS[1]

(Thousand metric tons and thousand dollars)

	2001	2002	2003	2004	2005
United States:					
Sold or used by producers:					
Quantity:					
Gross weight[2]	1,050	1,050	1,150	1,210	1,150
B_2O_3 content	536	543 r	605 r	637	612
Value	506,000	513,000	591,000	626,000	713,000
Exports:[3]					
Boric acid:[4]					
Quantity	85	84	70	61	183
Value	47,000	44,600	36,400	34,900	96,800
Sodium borates:					
Quantity	221	150	131	135	308
Value	91,700	63,100	55,400	60,200	110,000
Imports for consumption:					
Borax:[3]					
Quantity	1	(5)	(5)	(5)	1
Value	642	94	19	62	319
Boric acid:[3]					
Quantity	56	49	47	49	52
Value	21,700	18,500	19,000	20,300	22,500
Colemanite:					
Quantity[6]	35	32	24	21	31
Value	9,790	8,960	6,960	6,070	8,900
Ulexite:					
Quantity[6]	109	125	80	110	103
Value	21,800	25,000	16,000	21,900	31,000
Consumption, B_2O_3 content	347	359	366 r	385	W
World, production	4,730	4,590 r	4,730 r	5,070 r	4,910 e

eEstimated. rRevised. W Witheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits.

[2]Minerals and compounds sold or used by producers, including actual mine production, and marketable products.

[3]Source: U.S. Census Bureau.

[4]Includes orthoboric and anhydrous boric acid. Harmonized Tariff Schedule of the United States codes 2840.19.0000, 2840.30.0000, and 2840.20.0000.

[5]Less than ½ unit.

[6]Source: Journal of Commerce Port Import/Export Reporting Service.

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TABLE 2
BORON MINERALS OF COMMERCIAL IMPORTANCE

Mineral[1]	Chemical composition	B_2O_3, weight percentage
Boracite (stassfurite)	$Mg_3B_7O_{13}Cl$	62.2
Colemanite	$Ca_2B_6O_{11}·5H_2O$	50.8
Datolite	$CaBSiO_4OH$	24.9
Hydroboracite	$CaMgB_6O_{11}·6H_2O$	50.5
Kernite (rasortie)	$Na_2B_4O_7·4H_2O$	51.0
Priceite (pandermite)	$CaB_{10}O_{19}·7H_2O$	49.8
Probertite (kramerite)	$NaCaB_3O_9·5H_2O$	49.6
Sassolite (natural boric acid)	H_3BO_3	56.3
Szaibelyite (ascharite)	$MgBO_2OH$	41.4
Tincal (natural borax)	$Na_2B_4O_7·10H_2O$	36.5
Tincalconite (mohavite)	$Na_2B_4O_7·5H_2O$	47.8
Ulexite (boronatrocalcite)	$NaCaB_5O_9·8H_2O$	43.0

[1]Parentheses include common names.

TABLE 3
U.S. CONSUMPTION OF BORON MINERALS AND COMPOUNDS, BY END USE[1, 2]

(Metric tons of B_2O_3 content)

End use	2004	2005
Agriculture	9,360	W
Borosilicate glasses	19,800	W
Enamels, frits, glazes	9,930	W
Fire retardants:		
Cellulosic insulation	12,700	W
Other	2,380	W
Insulation-grade glass fibers	178,000	W
Metallurgy	181	W
Miscellaneous uses	45,400	W
Nuclear applications	124	W
Soaps and detergents	18,300	W
Sold to distributors, end use unknown	27,000	W
Textile-grade glass fibers	61,900	W
Total	385,000	W

W Withheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes imports of borax, boric acid, colemanite, and ulexite.

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TABLE 4

YEAREND PRICES FOR BORON MINERALS AND COMPOUNDS[1]

(Dollars per metric ton)

Product	Price, December 31, 2004	Price, December 31, 2005
Borax, technical, anhydrous, 99%, bulk, carload, works[2]	900-930	900-930
Borax, technical, anhydrous, 99%, bags, carload, works[2]	846	NA
Borax, technical, granular, decahydrate, 99%, bags, carload, works[2]	378	378
Borax, technical, granular, decahydrate, 99.5%, bulk, carload, works[3]	374	340-380
Borax, technical, granular, pentahydrate, 99.5%, bags, carload, works[2]	426	426
Borax, technical, granular, pentahydrate, 99.5%, bulk, carload, work[2]	400-425	400-425
Boric acid, technical, granular, 99.9%, bags, carload, works[2]	836	836
Boric acid, technical, granular, 99.9%, bulk, carload, works[2]	788	NA
Boric acid, United States Borax & Chemical Corp., high-purity anhydrous, 99% B_2O_3, 100-pound-bags, carlots[2]	1,996	900-935
Colemanite, Turkish, 42% B_2O_3, ground to a minus 70-mesh, free on board (f.o.b.) railcars, Kings Creek, SC[3]	270-290	270-290
Ulexite, Lima, 40% B_2O_3, ground to a minus 6-mesh, f.o.b railcars, Norfolk, VA	200	250-300

NA Not available.

[1]U.S. f.o.b. plant or port prices per metric ton of product. Other conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiation and/or somewhat different price quotations. Values have been rounded to the nearest dollar.

[2]Source: Chemical Market Reporter, v. 267, no. 1, January 3, 2005, p. 20; pricelist April 17-23, 2006.

[3]Source: Industrial Minerals, no. 448, January 2005, p. 72; no. 459, December 2005, p. 70.

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TABLE 5

U.S. EXPORTS OF BORIC ACID AND REFINED SODIUM BORATE COMPOUNDS, BY COUNTRY[1]

	2004			2005		
	Boric acid[2]		Sodium	Boric acid[2]		Sodium
Country	Quantity (metric tons)	Value (thousands)	borates[3] (metric tons)	Quantity (metric tons)	Value (thousands)	borates[3] (metric tons)
Australia	1,910	$849	4,530	1,900	$931	6,680
Belgium	11	24	144	--	--	102
Brazil	890	525	1,700	2,640	1,420	875
Canada	5,180	3,580	44,500	5,350	3,850	50,400
China	9,630	4,510	23,000	20,600	9,700	62,100
Colombia	34	29	2,650	54	53	4,430
France	35	27	1	125	111	117
Germany	978	1,040	8	432	1,070	11
Hong Kong	6,230	2,740	449	4,350	2,080	317
India	1	3	100	701	254	9,010
Indonesia	1,090	587	3,080	586	341	310
Italy	2	7	2,560	40	53	3,440
Japan	14,600	9,780	18,000	22,500	21,300	24,300
Korea, Republic of	7,310	3,620	5,750	19	9,820	14,900
Malaysia	769	567	1,570	1,370	1,080	20,000
Mexico	3,030	1,730	7,730	2,870	1,680	11,100
Netherlands	11	7	3	53,500	20,800	57,900
New Zealand	445	184	2,560	817	414	2,880
Philippines	133	81	1,230	111	68	1,130
Singapore	822	436	1,290	950	541	753
Taiwan	5,030	2,480	3,800	23,000	11,900	4,100
Thailand	2,610	1,850	7,000	3,520	1,940	7,240
United Kingdom	7	35	1	1,600	646	1,500
Venezuela	75	77	240	72	80	400
Vietnam	172	84	759	1,170	615	1,440
Other	64	69	2,290	34,700	6,040	22,300
Total	61,000	34,900	135,000	183,000	96,800	308,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States (HTS) code 2810.00.0000.

[3]HTS codes 2840.19.0000, 2840.30.0000, and 2840.20.0000.

Source: U.S. Census Bureau.

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TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF BORIC ACID, BY COUNTRY[1]

Country	2004		2005	
	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Argentina	1,340	$579	1,630	$694
Australia	15	40	1	2
Bolivia	2,680	985	3,840	1,360
Chile	12,800	4,670	15,100	6,130
China	1	2	32	83
France	488	813	1,270	1,720
Germany	27	46	22	31
India	12	22	13	28
Italy	1,210	1,320	1,290	1,500
Japan	157	148	109	160
Korea, Republic of	18	7	--	--
Peru	4,340	1,610	4,610	1,700
Russia	411	179	67	40
Turkey	25,800	9,730	23,900	8,970
United Kingdom	78	115	57	107
Other	21	22	21	23
Total	49,400	20,300	51,900	22,500

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]U.S. customs declared values.

Source: U.S. Census Bureau.

TABLE 7

BORON MINERALS: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country	2001	2002	2003	2004	2005[e]
Argentina	632 [r]	516 [r]	512 [r]	821 [r]	820
Bolivia, ulexite	32	40	110	68 [r]	68
Chile, ulexite	328	431	401	594 [r]	590
China[e, 3]	150	145	130	135	140
Germany, borax[e]	1	1	1	1	2
Iran, borax[4]	3	2	3 [r]	3	3
Kazakhstan[e]	30	30	30	30	30
Peru	9	7	9	9 [r]	9 [p]
Russia[e, 6]	1,000	1,000	1,000	500	400
Turkey[7]	1,493	1,346 [r]	1,377 [r]	1,697 [r]	1,700
United States[8]	1,050	1,050	1,150	1,210	1,150 [5]
Total	4,730	4,590 [r]	4,730 [r]	5,070 [r]	4,910

[e]Estimated. [p]Preliminary. [r]Revised.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through May 20, 2006.

[3]Boron oxide (B_2O_3) equivalent.

[4]Data are for years beginning March 21 of that stated.

[5]Reported figure.

[6]Blended Russian datolite ore that reportedly grades 8.6% B_2O_3.

[7]Concentrates from ore.

[8]Minerals and compounds sold or used by producers, including both actual mine production and marketable products.

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BROMINE

Phyllis A. Lyday

Domestic survey data and tables were prepared by Maria Arguelles, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

Bromine is one of two elements that are liquid at normal temperatures. Bromine is found principally in seawater, salt lakes, and underground brines associated with oil. In 2005, the quantity of bromine sold or used in the United States was 226 million kilograms (Mkg) valued at $168 million (table 1). The average value of bromine sold or used was $0.74 per kilogram (table 1). Primary uses of bromine compounds were in flame retardants (FRs), drilling fluids, brominated pesticides (mostly methyl bromide), and water-treatment chemicals. World production of bromine, in descending order and percentage of total, for 2004 was estimated to be as follows: United States, 41%; Israel, 38%; China, 8%; Jordan, 8%; and other countries, 5% (table 5). Because of depleting reserves, distribution and economics, environmental constraints, and the emergence of Israel as the world's second-ranked producer, the United States portion of world production has decreased steadily since 1973, when the United States produced 71% of the world's supply.

Legislation and Government Programs

The cost of security and the price of natural gas had a depressing effect on the U.S. chemical industry, including bromine. The leading end use for bromine is in FRs that is used in plastic products. Natural gas used for electrical energy generation and heating competed with gas used in manufacturing plastics. During 2005, prices for petroleum and natural gas continued to increase, and the chemical industry called for a domestic energy policy.

On November 29, New Jersey became the first State in the Nation to introduce mandatory standards for chemical plant security. There are no equivalent national standards. The State's 140 chemical facilities are required to implement existing "best security practices" guidelines. These guidelines were largely crafted by the chemical industry and based on the American Chemistry Council's responsible care security codes (Ember, 2005, p. 13).

The pesticide methyl bromide was listed as a class I ozone-depleting substance in the 1990 Clean Air Act (CAA). Methyl bromide is a broad spectrum pesticide used in the control of nematodes, pathogens, pest insects, rodents, and weeds. Domestically, methyl bromide had proven to be difficult to replace because of its low cost and usefulness against a large variety of agricultural pests. Under the Montreal Protocol, developing countries had until 2015 to phase out methyl bromide production. Countries may request exemptions from phaseout requirements for uses where there are no feasible technical or economical alternatives. The United States made a formal request to the Ozone Secretariat of the United Nations to allow use of methyl bromide after the January 1, 2005, phaseout deadline. The United States and 11 other developed countries were approved to continue to use the fumigant in 2005. The United States is allowed to use methyl bromide at 37% of its 1991 baseline level in 2005 and at 32% in 2006. For the 2007 calendar year, the United States nominated use at 29% of baseline, and 26.4% of baseline was authorized for critical use (U.S. Environmental Protection Agency, 2006§[1]).

Production

Domestic production data for bromine were developed by the U.S. Geological Survey (USGS) from a voluntary canvass of U.S. operations. All of the seven operations to which a canvass form was sent responded (table 2).

Domestic production comes from brine wells in Arkansas and Michigan. After bromine processing, the spent brine was returned underground into the production formation by class V injection wells that are regulated by the U.S. Environmental Protection Agency (EPA). The chemical composition of the spent brine is generally similar to that of the original, except that the concentration of the target elements (such as bromine and magnesium) is reduced, and the concentration of other elements (such as calcium) may have increased through substitution (U.S. Environmental Protection Agency, 1999, p. 1, 2, 5). Brine in Arkansas is found in the Smackover Formation at a depth of about 2,400 meters (m) (8,000 feet) with concentrations of 4,000 to 4,600 parts per million (ppm) bromine.

Albemarle Corporation operated the Magnolia South and Magnolia West plants in Columbia County, AR, which produced bromine, inorganic bromides, and brominated FRs (BFRs) and the satellite plant at Marysville, AR, in Union County, which produced bromine. In addition, it maintained two facilities in Baton Rouge, LA, to conduct research and product development and to produce additives, catalysts, and FRs. Albemarle announced in 2005 that the active brine rights and leasing program was expected to provide the company with 50 years of proven bromine reserves (Albemarle Corp, 2005§).

Great Lakes Chemical Corp. merged on March 9 with Compton Corp. to form Chemtura Corp. Chemtura continued production of bromine from brines at plants in Union County, AR. Production was from the El Dorado Central, El Dorado South, Marysville West, and Newell plants. At yearend, the installation of a new well for the extraction of elemental bromine was announced. A chlorine plant to be built at the site of a bromine facility in El Dorado, AR, by Ashta Chemicals was announced. Associated Octel Co. Ltd. of the United Kingdom, which produced bromine from seawater, had closed in 2004.

TETRA Technologies, Inc. was one of the leading users of clear brine fluids (CBFs) in the world. Calcium bromide and zinc bromide were purchased by TETRA from two domestic

[1]References that include a section mark (§) are found in the Internet References Cited section.

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manufacturers and one foreign manufacturer. TETRA also recycled calcium- and zinc-bromide CBFs repurchased from its oil and gas customers. Its West Memphis, AR, facility produced calcium bromide and zinc bromide. TETRA began operation of an elemental-bromine, calcium-bromide, and sodium-bromide plant at The Dow Chemical Company's Ludington, MI, facility in mid-1998, using crude bromine purchased from Dow's calcium-magnesium chemicals operation. TETRA also owned approximately 33,000 gross acres (13,400 hectares) of bromine-containing brine reserves that are under lease (TETRA Technologies, Inc., 2005§). At yearend, Tetra announced the building of a bromine plant using the leased brines.

Recycling

Hydrogen bromide is emitted as a byproduct in many organic reactions. This byproduct waste is recycled with virgin bromine brines and is a major source of bromine production. Bromine contained in plastics, such as FRs, can be incinerated as a solid organic waste, and the bromine can be recovered (Frim and Ukeles, 2006).

Consumption

The USGS did not collect consumption data on bromine compounds. Apparent consumption of bromine in the United States, calculated by the USGS from production, exports, and imports, remained at an estimated 224 Mkg. The United States was the world's leading market for bromine.

Flame Retardants.—It was estimated that about 50% of the consumption of bromine was used in BFR chemicals commonly used in many domestic and industrial appliances and such equipment as computers, furniture, insulation boards, mattresses, mobile phones, televisions, and many others. About 90% of electrical and electronic appliances contain BFRs to increase their resistance to fire. BFRs are also used in textiles for upholstered furniture.

Healthcare.—A major use of bromine compounds was in the manufacture of pharmaceuticals. Brominated substances are important ingredients of many over-the-counter and prescription drugs, including analgesics, antihistamines, and sedatives. Some bromine containing drugs have proved effective in the treatment of cocaine addiction and pneumonia.

Petroleum.—Bromine compounds are used as a constituent of antiknock fluid in leaded fuel still used in small aircraft, farm equipment, and in third world countries.

Calcium bromide, sodium bromide, and zinc bromide, collectively referred to as CBFs, were used in the oil- and gas-well-drilling industry for high-density, solids-free completion, packer, and workover fluids to reduce the likelihood of damage to the well bore and productive zone. Increased domestic energy demand during 2005 resulted in increased drilling, and therefore, increased used of bromine in completion and packing of the wells (Firm and Ukeles, 2006).

Photography.—Bromine compounds are used to make the light-sensitive component of a photographic emulsion. Other bromine compounds are used in ingredients in photographic development.

Sanitary Preparations.—Bromine compounds are effective pesticides, used both as soil fumigants in agriculture, particularly fruit growing, and as a fumigant to prevent pests from attacking stored grain and other produce. World trade in agriculture goods depends on the use of bromine compounds to ensure compliance with mandatory quarantine rules. Bromine compounds are also used as intermediates to make other agriculture chemicals.

Use of all pesticides, including methyl bromide, on crops in California increased in 2004 (the latest year for which data were available) compared with 2003. The fumigant methyl bromide, however, showed a decline of 4% (134,000 kg or 295,000 pounds) (Brank, 2006).

Water Purification.—One of the major uses of bromine is as a water purifier/disinfectant as an alternative to chlorine. Brominated compounds are used for water treatment in swimming pools and hot tubs and are also used to control algae and bacterial growth in industrial processes.

Transportation

Bromine in bulk quantities is transported in the United States in 7,570- and 15,140-liter (L) lead-lined pressure tank railcars or 6,435- to 6,813-L nickel-clad pressure tank trailers. The trailers must be filled at least 92% full to prevent inertia effects of the heavy liquid while on the highway. International shipments by The Dead Sea Bromine Group (DSBG) are in 15.2- to 23.3-metric ton (t) lead-lined tank containers (isotanks) with a volume of 5,300 to 8,000 L. For smaller quantities, lead lined tanks ("goslars") of 3.5 t (four tanks packed on one isoframe) and cylinders of 400 kilograms are used. Dry nitrogen gas is recommended for use in pressure transferring bromine, although dry air may be used. The gas used must be absolutely dry or severe corrosion results. When exposed to a high-humidity atmosphere, the water content of bromine can exceed 300 ppm. If the water content increases above 70 ppm, then the corrosiveness of bromine to many metals increases (Ukeles and Freiberg, 2002§).

Prices

At yearend 2005, U.S. bromine prices were 14% lower than those at yearend 2004. The price, however, at yearend 2000 was historically high because of demand in electronics.

Chemtura and Albemarle both announced a price increase for bromine and bromine compounds. Included in the compounds were clear brines and brine components used as oilfield completion, drill-in, and workover fluids. The price increase was the result of a rise in cost of energy, key raw materials, regulatory compliance, and transportation.

The export value of elemental bromine increased by 93% during 2005. The export value of bromine compounds, including ethylene dibromide and methyl bromide, increased by 22% during 2005.

The import value of elemental bromine increased by 15% compared with 2004 levels. The import values of some bromine compounds increased, except for potassium bromide, sodium bromate, and other bromide compounds, which decreased by 27%, 3%, and 11%, respectively.

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World Review

European Union.—The European Union made a decision to exempt the widely used BFR, deca-BDE, from its Restriction of Hazardous Substances. Deca-BDE was commonly used in computers, mattresses, mobile phones, office equipment, and TVs, upholstered furniture, and mattresses. Some 90% of all electrical and electronic appliances include BFRs (Greer, 2005).

Israel.—DSBG and Dead Sea Periclase announced its new corporate name, ICL Industrial Products (ICL-IP) in 2004. ICL-IP is the world's leading producer of elemental bromine and a leader in the development and supply of bromine compounds. ICL-IP was organized into six divisions. ICL-IP is a member of Israel Chemical Ltd., which includes Dead Sea Works, which controls potash and salt, and Rotem, which controls fertilizers. ICL-IP announced an increase in capacity from 40,000 metric tons per year (t/yr) to 240,000 t/yr by debottlenecking at its Sdom facility. The company also planned to use excess chlorine at the Sdom plant to manufacture bromine (Mining Engineering, 2005).

Jordan.—Jordan Bromine Company [a joint venture of Arab Potash Company Ltd. (APC) and Albemarle] produced bromine, calcium bromide, and sodium bromide at its plant at Safi on the Dead Sea. In 2004, production amounted to 46,000 metric tons. In December 2004, the company completed construction of its chlorine plant; this facility had a capacity of 25,000 t/yr (Albemarle Corp, 2005, p. 15).

Russia.—Bromine at a concentration of 5-9 kg/cubic meters (five times higher than the concentration of the Dead Sea) was discovered in the Volgograd Region. Bromine is 1 of 70 microelements contained in a large bischofite ($MgCl_2 6 H_2O$) deposit. The bischofite was confined to a Permian salt-bearing formation in two separate layers. The outer layer of Pricaspian bischofite was encountered in bedding lenses at a depth of 900 to 2,000 m. The inner part of the deposit occurred as lenses in salt domes at a depth of 900 to 4,000 m and was folded. The deposit, with bed-like occurrences of bischofite salt, was formed by two layers of chlorine-magnesium salt 20 to 25 m thick separated by halite and inclined to the west in the direction of the Pricaspian depression. The deposit extends for almost 400 kilometers along both banks of the Volga River. Bischofite comprises 80% to 90% of the formation; the rest is impurities of isomorphic bromine (0.45% to 0.95%) (JSC "Bischofite Avangard," Bischofite Mining, 2006§).

Current Research and Technology

Bromine was being investigated by Southern Company for the removal of mercury from exhaust in coal-fired powerplants. The clean air mercury rule finalized in 2005 required phase I reductions by 2010 and phase II in 2018. Current mercury control tests have used activated carbon that is disposed of along with fly ash. Halogens introduced into the coal-fired powerplants' exhaust can combine with mercury and deposit in the gypsum effluent of wet scrubbers. Tentative results indicated that only a fraction of the amount of bromine as compared with chlorine was required for nearly complete removal of the mercury. Tests by the Electric Power Research Institute projected bromine costs that were slightly more than costs for chlorine per 500 megawatt hours, but the reaction rate was approximately eight times quicker. The mercury bromide is insoluble and could be washed from the gypsum slurry, allowing for mercury-free wallboard (Monroe, 2006, p. 24).

Outlook

Flame Retardants.—Bromine is used as FR in plastics and also acts in synergy with many other materials to increase the overall effectiveness of the FR. Between 40% and 50% of domestic demand for bromine is for FRs. Although usage fluctuates along with overall cycles in the economy, assuming sustained economic growth, demand was expected to grow by 4% per year. The ban and voluntary withdrawal of two polybrominated diphenyl ether compounds resulted in a decrease in demand for bromine between 2001 and 2004. Recycling efforts in Europe for BFR plastics in electrical usage, which are easier to recycle than some other FR compounds, may increase the demand for BFR products because they are thought to be more environmentally friendly, especially by countries concerned with recycling, such as Japan. Growth was expected to increase in BFRs overall as the Consumer Product Safety Commission approves fire safety standards for upholstered furniture in the United States and if higher flammability standards are voluntarily adopted for TVs in Europe.

The Fredonia Group forecast FR value to grow in the United States by 6.5% per year through 2008 with volumes rising by 3.2% per year to more than 453,600 t. The highest growth rate was expected in BFRs with an annual rise of 7% to $600 million.

Healthcare.—The use of bromine in pharmaceuticals was expected to increase in antihistamines if pseudoephedrine, a key ingredient in illegal methamphetamines, is made a prescription product.

Photography.—Digital imaging can produce prints and overhead transparencies without the need for wet processing film. This would appear to cause a decrease in bromine usage in color film and film processing; however, 75% to 85% of all televised programs seen during prime time are recorded on 35-millimeter motion picture film and then transferred to videotape or laser disc for display, and the majority of feature films for movie theater presentations are shot and printed on film because film provides higher image resolution. As digital imaging technology improves and digital equipment and printers become more affordable in the next decade, future uses of bromine in film and film processing may be limited to specialty film imaging.

Petroleum.—Demand for bromine as a gasoline additive has declined since the 1970s when the EPA issued regulations to reduce and eliminate lead in automotive gasoline. In 1979, the amount of bromine sold for this application had reached a peak of 225 Mkg. The rapid decline to 141 Mkg in 1986 was a direct result of the limits on lead in leaded automotive gasoline. The Clean Air Act requires mobile sources, such as cars and trucks, to use the most effective technology possible to control emissions. Newer prototypes of the fuel cell that burn gasoline can double the mileage and decrease emissions

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by using unleaded gasoline or other nonbrominated fuels. The use of calcium-, sodium-, and zinc-bromides as CBFs in oil-well-completion and workover fluids has benefited in recent years from high gas and oil prices resulting from the increased demand for petroleum products. Increased demand for CBFs was expected to continue until alternative sources of fuel become available.

Sanitary Preparations.—The growth potential remains high for bromine-base biocides for use in industrial cooling systems because of environmental restrictions on chlorine and new alkaline-base chemical treatment programs. The most common bromine compounds used in cooling water are 1-bromo-3-chloro-5, 5-dimethylhydantoin and mixtures of sodium bromide with sodium hypochlorous acid. Bromine was used in indoor swimming pools, hot tubs, and whirlpools. Bromine has been found to be safer than its substitutes in sanitary preparations because bromine has a higher biocidal activity level for the same volume of product. The use of bromine compounds was expected to continue increasing in the spa and hot tub sector and to increase as a gentler disinfectant compared with chlorine in swimming pools.

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TABLE 1
SALIENT BROMINE AND BROMINE COMPOUNDS STATISTICS[1]

(Thousand kilograms and thousand dollars)

	HTS[2] number	2001	2002	2003	2004	2005
United States:						
Bromine sold or used:[3]						
Quantity		212,000	222,000	216,000	222,000	226,000
Value		159,000	166,000	155,000	191,000	168,000
Apparent consumption		214,000	216,000	210,000	224,000	224,000
Exports:[4,5]						
Elemental bromine:	2801.30.2000					
Quantity		3,710	6,070	2,280	2,840	2,710
Value		3,600	4,680	3,090	2,070	3,990
Bromine compounds:[6]						
Gross weight		7,990	8,000	7,160	7,850	8,130
Contained bromine		6,740	6,750	6,040	6,600	6,830
Value		14,900	13,600	11,800	13,800	16,800
Imports:[4,7]						
Elemental bromine:	2801.30.2000					
Quantity		5,610	2,020	1,920	2,650	2,740
Value		4,240	1,530	1,450	2,000	2,300
Bromine compounds:						
Ammonium bromide:	2827.59.2500					
Gross weight		59,700	16,900	46,600	3,310	58,200
Contained bromine		4,870	1,380	3,800	2,700	4,750
Value		29,200	8,850	21,100	1,520	30,400
Calcium bromide:	2827.59.2500					
Gross weight[8]		5,880	164	9	--	922 [8]
Contained bromine		4,700	131	7	--	--
Value		3,580 [e]	100 [e]	4 [e]	--	--
Potassium bromate:	2829.90.0500					
Gross weight		124	126 [8]	131 [9]	54	122
Contained bromine		59	36	63	26	58
Value		450	457 [e]	475 [e]	163	394
Potassium bromide:[9]	2827.51.0000					
Gross weight		433 [8]	171 [8]	497	598 [9]	434 [8]
Contained bromine		291	115	334	401	291
Value		1,060 [e]	417 [e]	1,210 [e]	1,800 [e]	1,310 [e]
Sodium bromate:	2829.90.2500					
Gross weight		1,020	1,020	967	992	950
Contained bromine		538	539	512	525	503
Value		2,190	2,020	2,010	1,930	1,860
Sodium bromide:[9]	2827.51.0000					
Gross weight[8]		NA	2,980 [8]	3,670 [8]	4,610 [8]	9,990 [8]
Contained bromine		NA	2,320	2,940	3,580	761
Value		NA	4,600 [e]	5,660 [e]	5,300 [e]	11,500 [e]
Other compounds:[10]						
Gross weight		5,950	4,920	3,280	4,630	5,400
Contained bromine		141	176	246	347	405
Value		5,360	6,090	19,000	19,400	17,300
World, production[e]		509,000 [r]	503,000 [r]	488,000 [r]	544,000 [r]	555,000

See footnotes at end of table.

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TABLE 1—Continued
SALIENT BROMINE AND BROMINE COMPOUNDS STATISTICS[1]

[e]Estimated. [r]Revised. NA Not available. -- Zero.
[1]Data are rounded to no more than three significant digits.
[2]Harmonized Tariff Schedule of the United States.
[3]Elemental bromine sold as such to nonproducers, including exports, or used by primary U.S. producers in preparing bromine compounds.
[4]Source: U.S. Census Bureau.
[5]Export values are free alongside ship.
[6]Source: U.S. Census Bureau. Includes methyl bromine and ethylene dibromide.
[7]Import values are cost, insurance, and freight.
[8]Source: The Journal of Commerce Port Import/Export Reporting Service.
[9]"Potassium bromide" and "Sodium bromides" import data are usually reported by a mutual HTS number, 2827.51.0000.
[10]Data for these compounds are derived from HTS number 2903.30.0500 (2001-02 and 2004-2005), and 2903.30.1520 (2002-05) information.

TABLE 2
ELEMENTAL-BROMINE-PRODUCING PLANTS IN THE UNITED STATES IN 2005

State and company	County	Plant	Production source	Capacity[1] (million kilograms)
Arkansas:				
Albemarle Corporation	Columbia	Magnolia South	Well brines	(2)
Do.	do.	Magnolia West	do.	(2)
Do.	Union	Satellite plant	do.	148 [2]
Chemtura Corporation	do.	El Dorado Central	do.	(3)
Do.	do.	El Dorado South	do.	71 [3]
Do.	do.	Marysville West	do.	36
Do.	do.	Newell	do.	23
Michigan, The Dow Chemical Company	Mason	Ludington[4]	do.	9
Total				287

[1]Actual production capacity is limited by brine availability.
[2]Cumulative capacity of Magnolia South, Magnolia West, and satellite plants.
[3]Cumulative capacity of El Dorado Central and El Dorado South plants.
[4]Bromine produced at this plant is reprocessed in Arkansas.

TABLE 3
U.S. IMPORTS OF OTHER BROMINE COMPOUNDS[1, 2]

		2004		2005		
Compound	HTS[3] number	Gross weight (kilograms)	Value[4] (thousands)	Gross weight (kilograms)	Value[4] (thousands)	Principal sources, 2005
Hydrobromic acid	2811.19.3000	753	$543	222	$286	Israel, 96%; other, 4%.
Ethylene dibromide	2903.30.0500	548	395	499	337	Israel, 100%.
Methyl bromide	2903.30.1520	821	2,690	327	1,620	Israel, 100%.
Dibromoneopentyl glycol	2905.50.3000	995	3,260	995	3,260	Israel, 99%.
Tetrabromobisphenol A	2908.10.2500	658	1,800	414	1,480	Israel, 96%; India, 2%; Japan, 2%.
Decabromodiphenyl oxide and octabromodiphenyl oxide	2909.30.0700	4,360	8,080 [e]	4,630	9,790	Israel, 99%; other, 1%.
Total		8,130	16,800	8,130	16,800	

[e]Estimated.
[1]These data detail the information included in table 1 under "Imports, bromine compounds, other compounds."
[2]Data are rounded to no more than three significant digits; may not add to totals shown.
[3]Harmonized Tariff Schedule of the United States.
[4]Declared cost, insurance, and freight valuation.

Source: U.S. Census Bureau.

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TABLE 4

WORLD BROMINE ANNUAL PLANT CAPACITIES AND SOURCES AS OF DECEMBER 31, 2005[1]

Country and company or plant	Location	Capacity (thousand kilograms)	Source
Azerbaijan, Neftechala Bromine Plant	Baku	4,000	Underground brines.
China, Laizhou Bromine Works	Shandong	43,000	Do.
India:			
Hindustan Salts Ltd.	Jaipur	NA	Seawater bitterns from salt production.
Mettur Chemicals Ltd.	Mettur Dam	NA	Do.
Tata Chemicals Ltd.	Mithapur	NA	Do.
Total		1,500	
Israel, Dead Sea Bromine Co. Ltd.	Sdom	210,000	Bitterns of potash production from surface brines.
Italy, Societa Azionaria Industrial Bromo Italiana	Margherita di Savoia	900	Seawater bitterns from salt production.
Japan, Toyo Soda Manufacturing Co. Ltd.	Tokuyama	20,000	Seawater.
Jordan, Jordan Bromine Co. Ltd.	Safi	50,000	Bitterns of potash production from surface brines.
Spain, Derivados del Etilo S.A.	Villaricos	900	Seawater.
Turkmenistan:			
Nebitag Iodine Plant	Vyshka	3,200	Underground brines.
Cheicken Chemical Plant	Balkan	6,400	Do.
Ukraine, Perekopskry Bromine Plant	Krasnoperckopsk	3,000	Do.

NA Not available.

[1]Excludes U.S. production capacity, which is detailed in table 2.

TABLE 5

BROMINE: ESTIMATED WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Thousand kilograms)

Country[3]	2001	2002	2003	2004	2005
Azerbaijan	2,000	2,000	2,000	2,000	2,000
China	40,000	42,000	42,000	43,000	43,000
France	2,000	2,000	2,000	2,000	2,000
Germany	500	500	500	500	500
India	1,500	1,500	1,500	1,500	1,500
Israel	200,000 r, 4	185,000 r, 4	176,000 r, 4	202,000 r, 4	210,000
Italy	300	300	300	300	300
Japan	20,000	20,000	20,000	20,000	20,000
Jordan	-- 4	-- r, 4	-- r, 4	46,000 r, 4	46,000
Spain	100	100	100	100	100
Turkmenistan	150	150	150	150	150
Ukraine	3,000	3,000	3,000	3,000	3,000
United Kingdom	27,900 r, 4	24,500 r	25,000 r	1,000 r	--
United States[5]	212,000 4	222,260 4	216,000 4	222,000 4	226,000 4
Total	509,000 r	503,000 r	488,000 r	544,000 r	555,000

rRevised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 26, 2006.

[3]In addition to the countries listed, several other nations, including Iran, produced bromine, but output data were not reported; available general information is inadequate to formulate reliable estimates of output levels.

[4]Reported figure.

[5]Sold or used by producers.

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CADMIUM

By Moungar E. Cooper and Peter H. Kuck

Domestic survey data and tables were prepared by Amy C. Tolcin, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

In the United States, three companies produced cadmium metal in 2005. Big River Zinc Corp. and Zinifex Ltd. (formerly Pasminco Ltd.) produced primary cadmium as a byproduct of the smelting and refining of zinc concentrates, while International Metals Reclamation Company Inc. (INMETCO) produced secondary cadmium from scrap, almost entirely from spent nickel-cadmium (NiCd) batteries. Cadmium metal production in the United States was 1,070 metric tons (t) in 2005, up 5% from that of 2004 (table 1). The total value of the 2005 output was estimated to be $3.5 million. Although definitive consumption data do not exist, the International Cadmium Association (ICdA) made the following estimates of cadmium consumption for various end uses in 2004: batteries, 81%; pigments, 10%; coatings and plating, 7%; stabilizers for plastics and similar synthetic products, 1.5%; and nonferrous alloys and other uses, 0.5% (Hugh Morrow, President, International Cadmium Association, oral commun., 2005). World production of refined cadmium metal has grown steadily since 2002, with more than 80% of the output being used to make NiCd batteries. The bulk of the additional output went to the rapidly growing battery industry in China.

The average New York dealer price of cadmium metal in 2005 was $3.30 per kilogram (or $1.50 per pound)—almost double the average for 2004 (table 1). Global prices for cadmium metal rose steadily between May 2004 and August 2005 owing to increased demand mainly from Chinese NiCd battery manufacturers. However, growing demand for zinc in the second half of 2005 resulted in increased byproduct cadmium output, causing cadmium prices to stabilize and later weaken. Increased secondary production, mainly from recycled NiCd batteries, also helped to stabilize prices. Some leading producers of primary cadmium in 2005 were Akita Smelting Co. Ltd. (Japan), Budel Zink BV (Netherlands), Falconbridge Ltd. (Canada), Hindustan Zinc Ltd. (India), Huludao Zinc Smelting Co. (China), JSC Chelyabinsk Electrolytic Zinc Plant (Russia), Korea Zinc Co., Ltd. (Republic of Korea), Met-Mex Peñoles, S.A. de C.V. (Mexico), Noranda, Inc. (Canada), Glencore AGPorto Vesme (Italy), Teck Cominco Ltd. (Canada), Toho Zinc Co. Ltd. (Japan), Zhuzhou Smelter Group Co., Ltd. (China), and Zinifex Ltd. (Australia).

Legislation and Government Programs

Government agencies around the world are making efforts to reduce the exposure of their citizens to cadmium. Prolonged exposure to excessive amounts of the element can damage the central nervous system, liver, and kidneys. Recent international studies also indicate a correlation between excessive cadmium and certain lung and pancreatic diseases (Kriegel and others, 2006; Nordberg, 2006). Environmental pollution is one of the main ways that ordinary citizens are exposed to dangerous levels of cadmium. The principal routes of exposure are ingestion and inhalation. Cadmium's relatively long biological half-life of about 10 years allows for considerable bioaccumulation. Owing to the fact that the tobacco plant concentrates cadmium effectively, smokers are particularly at a high risk for overexposure (Centers for Disease Control and Prevention, 2005§[1]). Within the body, cadmium can accumulate in the kidneys, leading to proteinuria, increased bone loss, and several cancers (Genova Diagnostics, 2005§). The human body contains metallothionen—a protein that binds heavy metals and lessens their impact on the body's systems. This protein reportedly binds cadmium in the liver, but its subsequent degradation in the kidneys leads to the release of intracellular cadmium. According to the Agency for Toxic Substances and Disease Registry (2005§), if the kidneys do not produce enough of the binding protein to sequester high levels of cadmium, renal dysfunction is possible. A recent study found a significant correlation between high serum cadmium levels and pancreatic cancer (Kriegel and others, 2006).

The U.S. Environmental Protection Agency (EPA) lists cadmium as a "priority" chemical, a designation intended to decrease the exposure of the general population to this toxic element. In 2005, the EPA reached its goal of reducing the release of priority chemicals in waste by 50% from the 1991 baseline. The EPA hopes to increase reduction an additional 10% by 2008 (U.S. Environmental Protection Agency, 2007§).

On July 21, the Centers for Disease Control and Prevention (CDC) reported that 5% of the population aged 20 years and older have urinary cadmium levels at or above the established safe level of 1 microgram per gram of creatinine. The CDC believes that cigarette smoking is the most probable source of this high level of cadmium (Centers for Disease Control and Prevention, 2005§).

In June, the EPA published a draft of its "Framework for Inorganic Metals Risk Assessment" for public comment. For more than a decade, the U.S. Government has worked to establish a scientific method for evaluating the effects of different metals on human health and the environment. Key issues have been the ecological effects of metals, their environmental chemistries, exposure pathways, and human health effects (with particular emphasis on bioaccumulation and bioavailability). In February, the EPA-nominated Science Advisory Board (SAB) reviewed the draft framework together with the public comments. The SAB recommended that the framework be restructured to improve the clarity of its overall purpose and that several major revisions be made. At the end of the year, the EPA's Office of Research and Development was in the process of restructuring the framework, with an

[1]References that include a section mark (§) are found in the Internet References Cited section.

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emphasis on updating the human health and ecological sections of the document. The SAB panel agreed with the framework's authors that metals should be assessed differently than organic pollutants because metals do not degrade like most organic compounds. The SAB also pointed out that some metals are essential for living organisms.

In addition to Federal regulations, 13 States have passed legislation regulating battery labeling and removeability from consumer products. Eight States now have take-back requirements that apply to all NiCds. The most stringent take-back regulations are in Minnesota, where 90% of NiCd and small sealed lead-acid batteries must be recovered. In New Jersey, manufacturers are required to take responsibility for used rechargeable batteries and either recycle or dispose of them in an environmentally sound manner (Fishbein, 1996§). In California, retailers of cellular phones are required to recycle old telephones at no cost to consumers after July 1, 2006 (Recycling Today, 2004§). An estimated 40,000 cell phones per day were being thrown away in California (Ursery, 2004§).

Similar efforts are underway worldwide. The European Union (EU) has implemented several regulations limiting the usage of cadmium. On January 19, the Environmental Council of the European Union enacted a new directive (2002/95/EC) on batteries and accumulators. The directive was designed to halt unregulated dumping and incineration of waste batteries. The most controversial part of the directive was a partial ban on portable cadmium batteries which stated that the cadmium content of a battery cannot exceed 0.002% unless the battery is used in emergency or medical systems. In addition, NiCd batteries would have to be collected and recycled. Collection targets for portable household batteries were 25% and 45% to be achieved in 4 and 8 years, respectively, after the transposition of the directive into the laws of each member country (European Parliament and The Council of the European Union, 2003§; United Kingdom Department for Environment, Food and Rural Affairs, 2005§).

After December 31, companies manufacturing pure electric or hybrid-motor vehicles for sale in the EU are prohibited from using cadmium in their batteries. Honda Motor Co., Ltd. of Japan was one of the first automobile manufacturers to comply with the new EU regulations (Honda Motor Co., Ltd., 2005§). Beginning in 2009, NiCd batteries can only be sold in the EU as replacement parts for older, grandfathered vehicles.

In February 2003, the EU had adopted a set of environmental regulations that are having a profound impact on semiconductor and electronics manufacturing. The "Restriction of the Use of Hazardous Substances" (RoHS) directive, which went into effect on July 1, 2006, is affecting electronic-circuit design worldwide. The directive restricts the incorporation of cadmium, hexavalent chromium, lead, and mercury in most electrical and electronic equipment sold in the EU after the 2006 deadline. The directive covers computers, DVD players, electronic tools and toys, household appliances, radios, telephones, televisions, and many other products. However, cadmium plating is exempt from the RoHS. Under a related directive, "Waste from Electrical and Electronic Equipment" (WEEE), the EU holds manufacturers financially responsible for the collection and recycling of used electronic products. The WEEE directive went into effect on August 13, 2005 (Katz, 2005§).

Production

Primary.—All of the primary cadmium recovered in the United States in 2005 came from lead and/or zinc concentrates. At least 10 mines produced lead and/or zinc concentrates, the leading mine being the Red Dog Mine in Alaska. Red Dog, which is the leading zinc mine in the world, is operated by Teck Cominco Ltd. under an agreement with NANA Regional Corporation, Inc. Teck Cominco also operates the Pend Oreille zinc mine in the State of Washington. Part of the concentrates from these two mines were exported to Canada to the company's metallurgical complex at Trail, British Columbia. Lead and/or zinc concentrates were also produced in Alaska, Idaho, Missouri, and Montana..

Primary cadmium was recovered and refined in two States—Illinois and Tennessee. Big River Zinc complex (BRZ) at Sauget, IL, is the second ranked electrolytic zinc refinery in the United States and has been producing zinc since 1929. In 1997, Korea Zinc Ltd. purchased BRZ for $50 million and spent more than $80 million upgrading the operation. In the past, the refinery relied on zinc concentrates from Illinois, Missouri, and Tennessee, which contained relatively low iron. When the mines from these locations closed, BRZ was unable to source suitable zinc concentrates at an attractive price. Because the refinery does not have a hot acid leach circuit, it is unable to process zinc concentrates with a high iron content, exacerbating the feed purchasing problem. In December, Korea Zinc idled the Sauget plant and put it up for sale (American Metal Market, 2005a§). In early 2006, ZincOx Resources plc of Surrey, United Kingdom, acquired BRZ, with the intent of converting the Sauget plant in part to secondary zinc production (ZincOx Resources plc, 2006).

All of the Tennessee cadmium production was a byproduct of the zinc smelting and refining operations at Clarksville, 80 kilometers (km) northwest of Nashville, TN. The smelter, located in Montgomery County, is owned and operated by Zinifex Ltd. of Melbourne, Australia. Clarksville is the smallest of Zinifex's smelting and refining complexes and has a capacity of 110,000 metric tons per year (t/yr) of zinc metal (Zinifex Limited, 2005). The complex also produces 145,000 t/yr of byproduct sulfuric acid. Much of the cadmium produced at Clarksville in 2005 was recovered from zinc concentrates imported from Australia, Central America, Ireland, and South America. Prior to 2004, the Clarksville smelter obtained the bulk of its cadmium-bearing zinc concentrates from the Gordonsville and Clinch Valley Mines in Tennessee. Gordonsville (Smith County) was closed in 2003; Clinch Valley (Grainger County), in 2004.

The zinc operations of ASARCO LLC (Asarco) in northeastern Tennessee were idle throughout 2005 and did not produce any cadmium. In November 2001, Asarco suspended operations at its Coy, Immel, and Young underground mines in the Mascot-Jefferson City district. The Young mill at Strawberry Plains (Jefferson County) was placed on care-and-maintenance status at the same time. In November 2005, Glencore AG of Switzerland bought Asarco's Tennessee operations for an undisclosed sum (Metallurgical Industry of Russia, 2006§).

On November 9, HudBay Minerals Inc. (Canada) announced that it would reopen its Balmat No. 4 zinc mine in New York State. The underground mine, located on the western edge of Lawrence County, had been on care and maintenance since 2001.

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Some sphalerite at Balmat reportedly contains 1,200 to 1,400 micrograms of cadmium per gram of zinc sulfide ZnS (Doe, 1960; Lenker, 1962). St. Lawrence Zinc Company (SLZ) (a wholly owned subsidiary of HudBay) will operate the mine. HudBay is the third ranked producer of zinc metal in Canada and operates mines and refineries in Manitoba and Saskatchewan. The Balmat Mine has 1.86 million metric tons (Mt) of ore reserves averaging 11.2% zinc and 1.39 Mt of additional, less defined resources averaging 12.9% zinc. At yearend, the existing 5,000-metric-ton-per-day concentrator was being overhauled. Production was scheduled to begin in June 2006 and was to be eventually ramped up to 60,000 t/yr of zinc in sphalerite concentrates. The concentrates would be shipped to the refinery of Canadian Electrolytic Zinc Limited in Valleyfield, Quebec, Canada, for further processing (HudBay Minerals Inc., 2005). The 60,000 t/yr of zinc equates to about 200 t/yr of cadmium.

Secondary.—Although primary cadmium production has declined somewhat since 2000, production of secondary cadmium has been increasing steadily. There are three major industry collection and recycling programs in the world—the Rechargeable Battery Recycling Corp. (RBRC) program in the United States and Canada, the Battery Association of Japan program, and the CollectNiCad program in Europe. The amount of cadmium being recycled, however, is difficult to estimate. The reported amount of NiCd batteries collected is fairly accurate, but there are no published data on the amounts of cadmium recovered from recycled batteries and other sources, such as electric arc furnace (EAF) dust, electroplating wastes, filter cakes, sludges, and other cadmium-containing materials. EAF dust typically contains about 0.05% cadmium.

The most difficult aspect of NiCd battery recycling has been the collection of spent batteries purchased for household use. Although large industrial batteries (containing about 20% of all cadmium used for batteries) are easy to collect and are recycled at a rate of about 80%, small consumer NiCd batteries are frequently discarded by the public. Voluntary industry-sponsored collection programs and government programs have been devised to improve the collection of these small consumer batteries and are continually being upgraded. Public participation is critical because, in addition to improving the environment, economies of scale are very important—larger recycling operations lower unit costs. The International Metals Reclamation Company, Inc. (INMETCO) has developed several different collection programs to meet the varied needs of battery manufacturers and the numerous consumers, firms, organizations, and agencies that use the many diverse products containing NiCd batteries (such as cordless phones, personal computers, and power tools). The most successful recycling program in the United States is operated by RBRC. Established when INMETCO began cadmium recycling in 1995, RBRC has organized a multifaceted collection program financed with proceeds from licensing its seal of approval to individual companies involved in the manufacturing, importation, and distribution of rechargeable batteries or battery-operated products. The RBRC recycling program includes uniform battery labeling, removeability from appliances, a national network of collection systems, regulatory relief to facilitate battery collection, and widespread publicity to encourage public participation. To increase participation, RBRC has undertaken an extensive public education campaign and has established numerous collection sites throughout the United States and Canada (Money and others, undated). In 2004, RBRC collected 1,500 t of NiCd batteries. In 2005, there was a 9.8% increase in the total number of rechargeable batteries collected by RBRC (Rechargeable Battery Recycling Corporation, 2006§).

Environmental Issues

For more than two decades, government agencies and nongovernmental environmental organizations worldwide have been expanding and improving their programs to monitor cadmium levels in the environment. The World Health Organization's (WHO) guideline for cadmium in drinking water is 0.003 milligrams per liter (mg/l) (World Health Organization, 2003§). Monitoring studies indicate that background levels are typically less than 0.002 mg/l. To improve detection, chemists at the University of New South Wales, Australia, have developed a voltammetric method for measuring cadmium ions using glutathione-modified gold electrodes and have reported a detection limit of 5 nanoMolar (Chow and others, 2005, p. 6).

The Agricultural Research Service (ARS) of the U.S. Department of Agriculture reported that acidifying cadmium-contaminated soil helped the plant alpine pennycress capture cadmium and zinc. The ARS believed that this technique could be very effective in decontaminating Asian rice paddies that have been contaminated with heavy metals from nearby mines (Agricultural Research Service, 2004§).

U.S. regulatory agencies cited and subsequently fined several companies for pollution-related violations linked to cadmium contamination. The Occupational Safety and Health Administration fined Project Management Services and Viasant L.L.C. for failing to comply with lead and cadmium standards, among other violations (Occupational Safety and Health Administration, 2006a§, b§). The EPA demanded that three companies, Container Properties L.L.C., Bayer Crop Science (successor of Rhone-Poulenc Inc.) and Rhodia Inc., pay more than $720,000 for failing to clean up the defunct Washington industrial chemical processing site in South Seattle, WA. Preliminary sampling detected heavy-metal contamination of surface groundwater flowing into the Lower Duwamish River, near the processing site. The river is home to the threatened Chinook salmon and is experiencing depressed steelhead runs (U.S. Environmental Protection Agency, 2005a§).

Asarco filed for Chapter 11 bankruptcy on August 17. Asarco, a leading smelter and refiner of nonferrous metals during the last century, has been accused of polluting the groundwater and soils of 22 Western States with arsenic, cadmium, and/or lead (U.S. Environmental Protection Agency, 2005c§). Asarco had more than 100 civil suits pending at the time of bankruptcy and could be required to spend more than $1 billion to clean up environmental contamination at 94 sites in 21 States (Millman and others, 2005).

The Government of the United Kingdom disclosed that some of its citizens had been intentionally exposed more than 40 years ago to above-background levels of cadmium. At the time, Ministry of Defense scientists wanted to simulate the airborne dissemination of chemicals in a possible airborne terrorist attack (British Broadcasting Corporation, 2005§). In five separate incidents from 1963-64, airplanes sprayed zinc cadmium chemicals over Suffolk, where the prevailing winds supposedly carried the dispersed

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chemicals northeast towards Norwich. An investigation was started to determine if the cadmium was linked to a suspected increase in esophageal cancer within the local population (Norwich Evening News, 2005§). After some investigation, public health officials concluded that it is unlikely that the zinc cadmium sulfide dispersion trials resulted in any long-term health effects.

Life Cycle Studies of Batteries.—Rydh and Karlström (2002) have studied the environmental impact of recycling portable NiCd batteries in Sweden. Their results showed that, in Sweden in 2001, 25% of NiCd batteries were recycled; 45%, incinerated; and 30%, landfilled. Their model indicated that batteries manufactured from recycled cadmium and nickel would have 16% lower primary energy requirements than if only virgin metals were used.

The European Commission has proposed stricter regulations on the disposal and end-of-life recycling of automobiles. Two major Japanese automakers recently revealed plans to produce cars with no cadmium, hexavalent chromium, lead, or mercury, except for the lead in lead-acid batteries (an end use where lead recycling exceeds 90%). Toyota Motor Corporation already has developed a mercury-free lamp and has ceased using lead in such parts as fuel tanks (Metal-Pages, 2004b§). Honda intended to abolish all applications of the four metals in its vehicles by yearend 2005, 2 years earlier than required by the Japan Manufacturers Association (Metal-Pages, 2005§).

Emissions From Lead and/or Zinc Smelters.—In March 2004, a team of environmental health specialists from the CDC visited the La Oroya copper and lead smelter in Peru (Doe Run Company, The, 2005§). Prolonged cadmium and lead emissions have been a concern at the Andean smelter for several decades. The Doe Run Company of St. Louis, MO, acquired Metaloroya (now Doe Run Peru) in 1997 from Centromin, a Peruvian parastatal, with the understanding that the U.S.-based company would improve operational efficiencies, reduce hazardous metal emissions, and dramatically increase industrial safety. Since then, Doe Run has spent $140 million on facility improvements designed to reduce plant emission and improve community life. The CDC team was to provide technical assistance to the project and recommend ways of further reducing exposure to lead, cadmium, and other contaminants. In May 2005, the team submitted its recommendations in a report to the Government of Peru and the U.S. Agency for International Development (Centers for Disease Control and Prevention, 2005). The long-term environmental remediation project currently underway at the La Oroya smelter illustrates how similar pollution problems can be alleviated at other nonferrous smelters worldwide (Doe Run Company, The, 2005§). As a result of these improvements, lead levels in the blood of Doe Run workers have fallen by more than 30% on average. Air lead emissions of the main stack are down by more than 35% since 1998 (Doe Run Company, The, 2005). Doe Run is planning to spend an additional $150 million on sulfur emissions abatement (Moore, 2005§). Remediation efforts to address historical soil contamination by arsenic, cadmium, and lead cannot be completely addressed until air emissions from the smelter are fully controlled.

Consumption

The U.S. Geological Survey (USGS) does not collect consumption data on cadmium metal or cadmium compounds. Apparent consumption of cadmium metal in the United States is calculated by the USGS using the production data of individual companies, U.S. foreign trade statistics, and reported stock changes (table 1).

According to the World Bureau of Metal Statistics, global consumption of refined cadmium in 2005 decreased to 16,100 t, 6% less than the tonnage for 2004 (World Metal Statistics, 2006, p. 35). Cadmium consumption in the 1990s was fueled by the growing NiCd rechargeable battery market. However, since 2002, consumption has weakened because of increasingly restrictive environmental regulations. During the 1990s, several battery manufacturing facilities relocated from Europe and North America to countries with less stringent environmental restrictions and lower labor costs. The main beneficiary of this transfer was China, which emerged as the leading cadmium consumer in the world, followed by Japan. Together, the two countries consumed more than one-half of world cadmium production in 2004 (Wilson, 2005). In 2005, China imported 6,800 t of cadmium metal, a 1% decrease from that of 2004; most of that imported cadmium was from the Republic of Korea, followed by Kazakhstan and the United States (Metal-Pages, 2006§). NiCd battery production in China was estimated to have increased to 800 million units in 2004, a 20% increase compared with that of 2003 (Wilson, 2005; Metal-Pages, 2004a§).

Recycling

In 2003 (latest available data), 150 million cell phones were in use in the United States, and they are replaced on average every 12 to 18 months. In 2003, 100 million cell phones were taken out of service in the United States, 60% to 70% was left by consumers in their home. Of the remaining 30% to 40%, only 5 million were refurbished or recycled, while at least 25 million were discarded in municipal waste sites. Although cell phones make up only a small percentage of the overall municipal waste stream, they may contain several toxic elements, such as cadmium, lead, and mercury (Wireless Recycling, 2004§).

In response to public concern about the environment, the cellular telephone industry in the United States joined the telephone recycling movement. As the stockpile of retired wireless devices continued to grow, the Cellular Telecommunications and Internet Association launched its initiative to promote environmentally sound recycling of used wireless products that contain cadmium, lead, lithium, and other hazardous metals. The association's "Wireless: The New Recyclable" program is designed to focus the public's attention on the importance and ease of recycling wireless devices (Recycle Wireless Phones, undated §).

The recycling of phones is typically carried out by contractors who turn consumer and industry discards into profit, reduce environmental waste, and at the same time help some nonprofit organizations. One of the latest companies to begin phone recycling is Global Refurbishment Corp. Wireless Recycling (GRC), headquartered in Miramar, FL. The company has formed a national partnership with businesses affected by the California Cell Phone Recycling Act of 2004. GRC pays $1 per pound or more for used telephones collected through 1,200 organizations in 49 States. The company has paid out

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more than $1.2 million since the partnership's establishment in 2001. About 70% of collected phones are refurbished and sold to buyers, mainly in Latin America, or given to nonprofit organizations. The remaining 30% is shredded and sold to nonferrous metal smelters for feed (Katz, 2004§).

Prices

In 2005, the average New York dealer price of cadmium increased to $1.50 per pound owing to increased demand from the battery industry and tightening supplies that carried into the summer (table 1). China was the main factor behind the 2005 price increase owing to the country's increased consumption (American Metal Market, 2005b§).

World Industry Structure

Worldwide production of cadmium in 2005 increased to 19,400 t from 18,700 t in 2004. Consumption declined by 8%, narrowing the gap between world production and consumption. The commissioning of new cadmium circuits at greenfield zinc mining and smelting complexes in Burkina Faso, China, and Russia offset the shutdown of older, less profitable operations in Belgium (table 5).

Worldwide consumption of cadmium for production of rechargeable batteries, which is the dominant use of cadmium, has been growing steadily for more than 15 years. Other cadmium markets, such as alloys, coatings, pigments, and stabilizers, are regarded as mature and are not expected to grow. Cadmium metal is commercially used as a corrosion-resistant coating on steel, aluminum, and other nonferrous metals, especially where low friction or low electrical resistivity is needed. Cadmium metal is also added to some nonferrous alloys to improve properties such as, castability, electrochemical behavior, hardness, strength, and wear resistance. Cadmium compounds are used in batteries, pigments, plastic stabilizers, and semiconductor applications.

Current Research and Technology

Ni-Cd Powered Buses.—Many cities are faced with the transportation challenge of getting commuters from houses to rails. Ebus Inc., Downey, CA, makes buses powered by NiCd batteries; these buses have four times the range of current electric buses. Among electric bus makers, Ebus has the most buses deployed in the United States (Fine, 2005§). Currently, there are 10 electric buses running in the main district of Santa Barbara, CA.

Solar Energy Applications.—A large portion of the solar energy operations around the world use cadmium in their photovoltaic (PV) modules. Cadmium sulfide acts as a 'window layer' because of its relative transparency. A cadmium telluride (CdTe) layer serves as the active region owing to its effective absorption throughout the solar spectrum (U.S. Department of Energy, 2005§). CdTe PV modules deliver virtually no greenhouse emissions, and cadmium emissions are considerably less than all other energy alternatives except natural gas (Fthenakis and Kim, 2006§). Each module contains less than 0.1% cadmium by weight and retains this cadmium for 20 to 30 years, after which it is recycled. CdTe PV modules represent a promising alternative to environmental discharge and NiCd batteries. According to the Brookhaven National Laboratory, CdTe modules provide 2,500 times more energy than NiCd batteries. Experts believe that there is more than enough cadmium to support this technology; the major downfall is cost. A considerable amount of energy is used in the production of each module, and more research is being done to decrease costs while increasing overall efficiency (National Renewable Energy Laboratory, 2005§).

Thin film PV solar panels may provide a more cost-effective alternative to traditional solar systems that rely on crystalline silicon wafers. Substantial progress has been made in improving CdTe-base thin-film solar cells. For more than 30 years, designers have relied on tin oxide (SnO_2)/cadmium sulfide (CdS)/CdTe device structures. Scientists at the National Renewable Energy Laboratory have improved the performance of these devices by incorporating cadmium stannate (Cd_2SnO_4) and zinc stannate (Zn_2SnO_4) into device structures. One such modified device had a total-area efficiency of 16.5%—the highest efficiency ever reported for CdTe solar cells (Wu and others, 2001, p. 2). This efficiency compares favorably with the efficiencies attained with thin-film copper indium aluminum diselenide devices (National Renewable Energy Laboratory, 2003a§, b§).

Semiconductor Applications.—In June 2004, TeraRecon, Inc. of San Mateo, CA, teamed up with Acrorad Co., Ltd. of Okinawa, Japan, to develop advanced CdTe semiconductor devices for use in direct conversion x- and gamma-ray detectors. CdTe is one of a few semiconductor materials that can convert x and gamma rays directly into electrical signals while attaining high conversion efficiency. Acrorad reportedly has overcome many of the difficulties that prevented competitors from manufacturing large monolithic CdTe crystals. Acrorad's facility on Okinawa reportedly is the largest CdTe production operation in the world in terms of volume. The two companies will focus their efforts initially on flat panel area-detectors and gamma-ray cameras. Both products would be sold to original equipment manufacturers and have numerous applications in the fields of industrial and medical imaging (TeraRecon, Inc., 2004).

Quantum Dots.—Cadmium selenide (CdSe) is being studied for its uses in biomedical imaging, lasers, luminescent materials, and optoelectronics. Quantum dots are tiny crystals of CdSe, a semiconducting material, that are used for their size-controlled fluorescence. Engineers at Johns Hopkins University have created a new method of identifying specific sequences of DNA by using quantum dots and their florescence under a microscope (Johns Hopkins University, 2005§). Owing to its increased sensitivity, this method can be used to find a specific DNA sequence or mutation. Researchers at the Massachusetts Institute of Technology are conducting animal studies which would use quantum dots to label cancerous tumors via Magnetic Resonance Imaging (Science Daily, 2006§). Scientists at the Los Alamos National Laboratory discovered that nanocrystals of cadmium compounds respond to photons by producing multiple electrons in a process called carrier multiplication (Los Alamos National Laboratory, 2006§). This technology could be used to make more efficient solar cells.

When CdSe is heated to several hundred degrees Celsius under the flow of nitrogen gas and a gold catalyst, it forms

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one-dimensional nanostructures—nanobelts, nanosaws, and nanowires. Georgia Institute of Technology scientists have determined the optimal conditions for growing each of these structures (Science Daily, 2005b§). Prior to 2005, quantum dots cost more than $2,000 per gram, with the production solvent octadecane contributing to 90% of this cost. Rice University scientists developed a new method that replaces octadecane with Dowtherm, a heat transfer oil, which decreases the cost of quantum dots by 80% (Science Daily, 2005a§).

Outlook

Cadmium producers and consumers face an unusual situation. Environmentalists oppose the proliferation of cadmium in any form because of the metal's toxicity. Consumers, meanwhile, are demanding computers, power tools, and other electric products that require the use of relatively inexpensive NiCd batteries. To date, nickel-metal hydride (NiMH) and lithium-ion batteries have been more expensive to manufacture than NiCd batteries and are not being used in many low-end products. The commercialization of novel nickel-zinc (Ni-Zn) batteries may change the current situation. San Diego, CA-based PowerGenix Corporation has developed and patented the next generation Ni-Zn battery that is up to ten times more powerful than traditional NiCd, NiMH, or lead-acid batteries, while up to 75% lighter and about 30% smaller. Venture capitalists have invested $13 million in Ni-Zn battery research hoping that the new battery will become an economically viable and environmentally friendly alternative to NiCd batteries (Metal-Pages, 2004c§). Chinese and Indian markets will continue to drive NiCd battery demand in the foreseeable future. China currently consumes more than twice as much cadmium as it produces, mainly to feed the country's burgeoning NiCd battery manufacturing industry (Plachy, 2005, p. 15.4).

If cadmium prices continue to strengthen, the growing supply deficit will be partially offset by improved recycling rates and the increased availability of recycled cadmium. According to a 1999 survey conducted by the RBRC, 95% of Americans own cordless electronic products, but only about 16% recycle their power sources (American Metal Market, 1999). Another survey conducted by the RBRC has highlighted America's growing reliance on cordless electronic products. The average U.S. household has five or more of these products, which include camcorders, cordless and cellular telephones, cordless power tools, electric toothbrushes, handheld mini-vacuums, laptop computers, and remote-controlled toys. The survey found that more than one-half of respondents would recycle their rechargeable batteries if the batteries were collected together with other recyclables through curbside collection programs at home, at businesses, or at retail stores that sell replacement batteries (Rechargeable Battery Recycling Corp., 2002§).

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TABLE 1
SALIENT CADMIUM STATISTICS[1, 2]

		2001	2002	2003	2004	2005
United States:						
Production of metal[3]	metric tons	1,450 r, 4	1,430 r, 4	1,420 r, 4	1,010 r, 4	1,070
Shipments of metal by producers[5]	do.	1,040 r	1,020 r, 4	995 r, 4	1,060 r, 4	1,050
Exports of metal, alloys, scrap	do.	216 r	264 r	615 r	154 r	686
Imports for consumption, metal, alloys, and scrap	do.	107 r	81 r	112 r	263 r	288
Stocks of metal, U.S. Government, yearend[6]	do.	773	146 r	--	--	--
Apparent consumption of metal	do.	1,000 r	1,460 r	637 r	1,170 r	656
Price, average, New York dealer[7]	dollars per pound	0.23	0.29 r	0.59 r	0.55 r	1.50
Do.[7]	dollars per kilogram	0.50	0.64	1.31	1.20	3.30
World, refinery production	metric tons	20,000 r	18,000 r	18,500	18,700 r	19,400 e

eEstimated. rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits, except prices.

[2]Cadmium content.

[3]Primary and secondary cadmium metal. Includes equivalent metal content of cadmium sponge used directly in production of compounds.

[4]Partially estimated.

[5]Includes metal consumed at producer plants to make oxide and other cadmium compounds.

[6]Defense National Stockpile Center, December 31. Includes material for sale pending shipment.

[7]Price for 1- to 5-short-ton lots of metal having a minimum purity of 99.95% (Platts Metals Week).

TABLE 2
SUPPLY AND APPARENT CONSUMPTION OF CADMIUM METAL[1, 2]

(Metric tons)

	2001r	2002r	2003r	2004	2005
Producer stocks, January 1[3]	1,350	1,540	2,160	2,580 r	2,540
Production[3]	1,450	1,430	1,420	1,010 r	1,070
Imports for consumption of metal, alloy, scrap	107	81	112	263 r	288
Shipments from Government stockpile excesses	68	627	146	--	--
Total supply	2,970	3,890	3,840	3,860 r	3,890
Exports of metal, alloys, scrap	216	264	615	154 r	686
Producer stocks, December 31[3]	1,750	2,160	2,580	2,540 r	2,550
Consumption, apparent[4]	1,000	1,460	637	1,170 r	656

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Excludes supply and apparent consumption of cadmium sulfide, cadmium telluride, and related cadmium chemicals.

[3]Partially estimated.

[4]Total supply minus exports and yearend stocks.

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TABLE 3

U.S. EXPORTS OF CADMIUM PRODUCTS, BY COUNTRY AND TYPES[1]

	2001		2002		2003		2004		2005	
	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value
Cadmium metal:[2]										
Belgium	--	--	--	--	79,900	$80,000	--	--	--	--
Brazil	9,110	$1,180,000	--	--	--	--	--	--	--	--
Canada	19,700	284,000	32,900	$509,000	10,700	229,000	20,200	$440,000	8,590	$211,000
Chile	--	--	1,150	11,700	--	--	2,080	3,600	--	--
China	72,700	196,000	156,000	143,000	183,000	211,000	19,900	18,200	337,000	421,000
Colombia	--	--	--	--	404	275,000	--	--	--	--
Costa Rica	--	--	6,610	15,200	--	--	--	--	--	--
Ecuador	--	--	121	2,840	--	--	--	--	--	--
Egypt	4,540	5,960	--	--	--	--	--	--	--	--
France	26,500	35,300	21,300	31,600	66,700	78,900	16,400	19,500	34,800	129,000
Germany	7,600	258,000	8,330	354,000	118	88,500	37,500	209,000	275	118,000
Hong Kong	3	2,510	--	--	--	--	--	--	--	--
India	--	--	14,500	8,810	38,500	12,000	--	--	--	--
Ireland	--	--	--	--	--	--	2	3,220	--	--
Israel	--	--	--	--	16,100	65,400	24,300	99,000	112	16,000
Japan	4,210	17,100	--	--	--	--	1	2,600	--	--
Jordan	9,550	16,000	21,900	19,200	--	--	--	--	--	--
Korea, Republic of	--	--	--	--	7	8,220	--	--	295,000	343,000
Mexico	1,160	324,000	297	47,900	125	23,300	2,640	19,800	110	56,400
Netherlands	--	--	--	--	168,000	219,000	--	--	--	--
New Zealand	85	8,440	--	--	--	--	--	--	--	--
Pakistan	37,600	76,000	--	--	--	--	21,100	24,500	--	--
Singapore	--	--	--	--	7,110	16,100	10,300	60,400	6,690	37,000
South Africa	5,200	17,700	1,000	101,000	--	--	--	--	--	--
Sweden	10	12,100	232	106,000	--	--	--	--	--	--
Switzerland	--	--	2	4,350	--	--	--	--	629	4,510
Taiwan	36	3,060	--	--	--	--	--	--	2,810	27,800
Thailand	--	--	--	--	3	2,610	--	--	--	--
United Kingdom	18,200	57,700	--	--	40,500	70,600	--	--	--	--
Venezuela	--	--	--	--	3,540	3,000	--	--	--	--
Total	216,000	2,500,000	264,000	1,350,000	615,000	1,380,000	154,000	899,000	686,000	1,360,000
Of which:										
Unwrought and powder	9,930	679,000	95,400	72,300	38,500	299,000	22,300	34,200	141	7,270
Waste and scrap	(3)	(3)	369	7,520	18,100	27,900	192	4,000	17,900	25,900
Other	206,000	1,820,000	168,000	1,270,000	558,000	1,060,000	132,000	861,000	668,000	1,330,000
Total	216,000	2,500,000	264,000	1,350,000	615,000	1,380,000	154,000	899,000	686,000	1,360,000

See footnotes at end of table.

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TABLE 3—Continued

U.S. EXPORTS OF CADMIUM PRODUCTS, BY COUNTRY AND TYPES[1]

	2001		2002		2003		2004		2005	
	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value
Cadmium sulfide, gross weight:										
Australia	--	--	--	--	--	--	--	--	12,900	$6,710
Belgium	--	--	--	--	--	--	25,600	$13,800	--	--
Canada	--	--	--	--	--	--	--	--	89,400	38,900
Chile	--	--	--	--	--	--	--	--	5,830	3,030
China	--	--	--	--	70,600	$36,700	--	--	--	--
Colombia	--	--	--	--	--	--	6,350	3,300	--	--
Germany	13,500	$7,000	12,100	$6,300	--	--	--	--	4,820	2,510
Israel	--	--	--	--	--	--	6,720	3,500	--	--
Japan	--	--	13,300	6,900	43,900	22,800	--	--	--	--
Korea, Republic of	--	--	--	--	--	--	38,500	12,300	--	--
Mexico	--	--	--	--	69,800	37,600	83,200	43,300	--	--
Philippines	30,800	16,000	--	--	--	--	--	--	--	--
Saudi Arabia	5,100	2,650	--	--	--	--	--	--	--	--
Singapore	3,000	6,000	--	--	--	--	--	--	--	--
Switzerland	--	--	--	--	--	--	--	--	7,440	3,870
Total	52,400	31,700	25,400	13,200	184,000	97,100	160,000	76,200	120,000	55,000
Total, calculated Cd content	40,800	XX	19,800	XX	143,000	XX	125,000	XX	93,700	XX

XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes exports of cadmium in alloys (Schedule B 8107.90) and scrap (Schedule B 8107.30).

[3]Prior to 2002, trade data on unwrought metal were combined with the data for waste and scrap in Schedule B 8107.10.

Source: U.S. Census Bureau.

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TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF CADMIUM PRODUCTS, BY COUNTRY AND TYPES[1]

	2001		2002		2003		2004		2005	
	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value	Quantity (kilograms)	Value
Cadmium metal:[2]										
Australia	58,900	$40,100	37,000	$32,600	37,000	$46,500	77,000	$97,300	53,000	$126,000
Belgium	15,700	126,000	12,600	154,000	9,090	119,000	8,530	121,000	12,100	192,000
Canada	13,200	1,630,000	15,100	1,450,000	27,000	756,000	19,100	332,000	41,400	1,000,000
China	--	--	34	16,200	20,100	197,000	22	6,700	39,000	116,000
Finland	--	--	--	--	2,000	2,890	--	--	--	--
France	--	--	89	14,400	--	--	14	30,300	--	--
Germany	2	2,490	--	--	24	4,090	80	16,100	243	37,300
Hong Kong	32	4,300	--	--	--	--	--	--	5,650	22,500
Japan	--	--	10	9,950	2	6,630	--	--	--	--
Mexico	16,400	13,600	16,400	8,820	16,400	26,300	37,900	51,500	97,000	239,000
Netherlands	--	--	--	--	--	--	2	8,540	--	--
Peru	--	--	--	--	--	--	--	--	40,000	89,000
Russia	--	--	--	--	--	--	--	--	3	24,300
United Kingdom	3,200	17,600	22	6,360	1	2,050	120,000	914,000	--	--
Total	107,000	1,830,000	81,200	1,700,000	112,000	1,160,000	263,000	1,580,000	288,000	1,850,000
Of which:										
Unwrought and powder	97,900	1,280,000	56,500	719,000	73,600	595,000	102,000	543,000	207,000	811,000
Waste and scrap	(3)	(3)	--	--	20,000	182,000	122,000	908,000	--	--
Other	9,400	558,000	24,700	978,000	18,000	383,000	38,000	127,000	81,300	1,040,000
Total	107,000	1,830,000	81,200	1,700,000	112,000	1,160,000	263,000	1,580,000	288,000	1,850,000
Cadmium sulfide, gross weight:										
China	--	--	20	9,280	3,840	10,600	--	--	50	5,000
Japan	5,160	24,000	--	--	--	--	--	--	--	--
Russia	106	11,600	--	--	--	--	--	--	6,890	47,000
United Kingdom	2,280	26,600	6,690	78,500	3,630	42,300	1,810	22,600	1,810	22,600
Total	7,550	62,200	6,710	87,700	7,470	52,900	1,810	22,600	8,760	74,600
Total, calculated Cd content	5,870	XX	5,220	XX	5,810	XX	1,410	XX	6,810	XX

XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes imports of cadmium in alloys [Harmonized Tariff Schedule of the United States (HTS) 8107.90] and waste and scrap (HTS 8107.30).

[3]Prior to 2002, trade data on unwrought metal were combined with data for waste and scrap in HTS 8107.10.

Source: U.S. Census Bureau.

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TABLE 5

CADMIUM: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Algeria[e]	10	8	5	--	--
Argentina	34	--	25	25 [e]	25
Australia	378	350	350 [e]	350 [e]	374
Belgium	1,236	117	-- [r]	-- [r]	--
Brazil[4]	120 [r]	151 [r]	189 [r]	187 [r]	200
Bulgaria	333	345	307	356 [r]	319 [5]
Canada[6]	1,493	1,706	1,759	1,880 [r]	1,703 [p]
China[e]	2,510	2,440	2,710	2,800	3,000
Finland[7]	604	4	-- [e]	--	--
France[7]	176	63 [r]	-- [r]	-- [r]	--
Germany	539	422	640 [r]	640 [r, e]	640
India	436	466	477	489	417 [5]
Italy	313 [r]	391	22 [r]	-- [r]	--
Japan	2,460	2,444	2,497	2,233	2,297 [5]
Kazakhstan	1,250 [e]	1,300	1,351	1,900	2,000
Korea, North[e]	200 [r]	200 [r]	200 [r]	200 [r]	200
Korea, Republic of	1,879	1,825 [r]	2,175 [r]	2,362 [r]	2,900
Macedonia[e]	73 [r]	111 [r]	75 [r]	-- [r]	--
Mexico[8]	1,421 [r]	1,382	1,590	1,594 [r]	1,600
Netherlands	455	485	495 [r]	572 [r]	575
Norway	372	209	331	260	260 [5]
Peru	485 [r]	422	529	532	481 [5]
Poland, metal, primary refined	330	440	375 [r]	356 [r]	350
Russia[e]	950	950	950	950	1,000
Ukraine[e]	25	25	25	25	25
United Kingdom	425 [r]	292 [r]	22 [r]	-- [r]	--
United States	1,450 [r, 9]	1,430 [r, 9]	1,420 [r, 9]	1,010 [r, 9]	1,070 [5]
Total	20,000 [r]	18,000 [r]	18,500	18,700 [r]	19,400

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]This table gives unwrought production from ores, concentrates, flue dusts, and other materials of both domestic and imported origin. Sources generally do not indicate if secondary metal (recovered from scrap) is included or not; where known, this has been indicated by a footnote. Data derived in part from World Metal Statistics (published by World Bureau of Metal Statistics, Ware, United Kingdom) and from Metal Statistics (published jointly by Metallgesellschaft AG of Frankfurt am Main, Germany, and World Bureau of Metal Statistics). Cadmium is found in ores, concentrates, and/or flue dusts in several other countries, but these materials are exported for treatment elsewhere to recover cadmium metal; therefore, such output is not reported in this table to avoid double counting. This table includes data available through May 13, 2006.

[2]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[3]Romania, Thailand, and Uzbekistan may produce primary cadmium metal or oxide, but information is inadequate to make reliable estimates of output.

[4]Exports from Anuário Mineral Brasileiro (Departamento Nacional de Produção Mineral).

[5]Reported figure.

[6]Includes secondary.

[7]Excludes secondary production from recycled nickel-cadmium batteries.

[8]Excludes significant production of both cadmium oxide and cadmium contained in exported concentrates.

[9]Partially estimated.

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CEMENT

By Hendrik G. van Oss

Domestic survey data and tables were prepared by D. Armand Marquardt, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Production, imports, and sales volumes and prices of cement all reached record high levels in 2005. Output of portland and masonry cements in the United States in 2005 rose by 1.9% to 99.3 million metric tons (Mt) (table 1). Production of clinker—the intermediate product in cement manufacturing—increased slightly to 87.4 Mt, also a record. The United States continued to rank third in the world in hydraulic cement production; world output in 2005 was about 2.3 billion metric tons (Gt). Notwithstanding disruptions caused by major hurricanes, sales of cement to domestic customers increased by 5.8% to about 127 Mt. Imports of cement increased by almost 20% to 30.4 Mt. Despite the higher domestic production and import levels, spot shortages of cement continued to be informally reported to the U.S. Geological Survey (USGS), although to a somewhat lower degree than in 2004. The continuing tight cement supplies and rising fuel costs led to large, although regionally variable, price increases (tables 11–12). Overall, the value of cement sales to domestic final customers increased almost 22% to about $11.6 billion (tables 1, 11–12). Based on typical portland cement mixing ratios in concrete, the delivered value of concrete (excluding mortar) in the United States in 2005 was estimated to be at least $51 billion.

Indications of percentage or other changes expressed in this report compare activity in 2005 with that of 2004 unless specified otherwise. Except where otherwise indicated, activity levels in this report exclude those in Puerto Rico. And except for some trade data, the cements covered in this report are limited to those hydraulic varieties broadly classified as portland and/or masonry cement. These cements are the binding agents in concrete and most mortars. Varieties included as portland cement are listed in table 15 and include blended cements[1]. Masonry cements include true masonry cements, portland-lime cements, and plastic cements; currently, the category does not include natural cement for mortar, minor production of which resumed in 2004 after a hiatus of 34 years. Certain other hydraulic cements (most notably aluminous cement) are included in the trade data in tables 16-18 and 21 (clinker) and within the world hydraulic cement production data given in table 22. Excluded from the U.S. data and, to the degree possible, from international data, are pure (unblended) supplementary cementitious materials (SCM) such as fly ash, other pozzolans, and ground granulated blast furnace slag (GGBFS). Although not finished cements in their own right, SCM are in common use as components of blended portland cements or as partial substitutes for portland cement in concrete. Detailed background information on cement and its manufacture is given in van Oss (2005§[2]).

The bulk of this report is based on data compiled from USGS annual questionnaires sent to cement and clinker manufacturing plants and associated distribution facilities and import terminals, some of which are independent of U.S. cement manufacturers. For 2005, forms were received from 146 of 150 facilities canvassed, a response rate of 97%. The responding facilities included all but three production sites and accounted for almost 98% of total cement sales. For 2004, forms were received from 148 of 150 facilities canvassed, a response rate of 99%. For missing or incomplete forms, telephone inquiries were made to obtain data, and 100% reporting of cement and clinker production tonnages was obtained for both years. Background information on the USGS cement canvasses is given in van Oss (2005§).

Legislation and Government Programs

Government economic policies and programs that affect the cement industry are those relating to cement and clinker trade, interest rates, and public sector construction spending. The major trade issue in 2005 continued to be that of antidumping tariffs against Japan and Mexico. For Mexico, the tariff rate in 2005 continued to be based on the 54.9% dumping margin determined by the U.S. Department of Commerce (DOC) for the 13th review period (August 2002 through July 2003) for gray portland cement and clinker. A preliminary determination announced August 31, 2005, for the 14th review period (August 2003 through July 2004) was for a lower, 40.54%, dumping margin, but the determination had not been finalized as of yearend. In any case, owing to widespread reports of cement shortages in 2004 and 2005, and notwithstanding the fact that imports of cement from Mexico in 2005 were already 52% higher than in 2004 and 145% higher than in 2003, there were calls from industry groups and some State Governments (Cement Americas, 2005a) to end or suspend the tariffs to encourage the importation of more cement from Mexico. Negotiations were underway towards this end between the DOC and the Mexican Government, and a resolution to this longstanding trade dispute was expected to be agreed to early in 2006.

The main Federal funding program in recent years relating to construction has been the $216.3 billion Transportation Equity Act for the 21st Century (TEA–21) and temporary funding continuations following its formal expiration in September 2003. Negotiations to reauthorize TEA–21 culminated with the August 10, 2005, signing into law of its replacement, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA–LU). This Act authorized Federal funding of surface transportation projects for the period 2005–09 at a total guaranteed minimum funding level of $244.1 billion for the period.

The major environmental issues relating to cement are associated with the production of clinker. The most significant

[1]Sales data for blended cements (also called composite cements) listed separately from portland cement are available within the monthly cement reports of the USGS Mineral Industry Surveys series, starting with January 1998.

[2]References that include a section mark (§) are found in the Internet References Cited section.

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emissions from clinker manufacture are of carbon dioxide (CO_2), slightly more than one-half of which is derived from the calcination of calcium carbonate raw materials, and the rest from the combustion of fuels. Overall, generation of CO_2 by the U.S. cement industry in 2005 amounted to about 84 Mt, or about 0.96 ton CO_2 per ton of clinker; this excluded emissions associated with the utility companies that generated the electricity used by the cement industry. The methodology for this calculation may be found in van Oss and Padovani (2003, p. 123-126). The cement industry was working on ways to reduce the unit emissions of CO_2, such as by encouraging the use of blended cements and of SCM in concrete. Also, the ASTM standard for portland cement was amended in 2004 to allow the incorporation of up to 5% ground limestone in the finished portland cement; this is reflected in the 2005 edition of the standard (ASTM C-150-05). As with adding SCM, this limestone addition potentially allows a commensurate increase to a plant's cement capacity without increasing the unit emissions of CO_2, provided that the limestone available to the plant does not adversely affect the cement quality. Widespread adoption of limestone addition was not expected unless the States' departments of transportation incorporate the practice into the otherwise similar American Association of State Highway and Transportation Officials (AASHTO) standard M85-89.

Production

In 2005, portland cement was produced in 37 States and Puerto Rico by 115 plants (table 3). Of these plants, 73 also produced masonry cement (table 4). Cement producers in the United States ranged widely in size and in the number of plants operated. Ranking companies in terms of output or capacity is difficult because of the existence of some common parent companies and joint ventures. With common parents combined under the larger subsidiary's name and with joint ventures apportioned, the 10 leading companies at yearend 2005 were, in descending order of cement production, Holcim (US) Inc.; Lafarge North America, Inc.; CEMEX, Inc.; Buzzi Unicem USA, Inc. (including Alamo Cement Co.); Lehigh Cement Co.; Ash Grove Cement Co.; Essroc Cement Corp.; Texas Industries Inc. (TXI); California Portland Cement Co.; and St. Marys Cement, Inc. The leading 5 of these had about 56% of total U.S. portland cement production, and the leading 10 together accounted for about 80% of total U.S. production. Of these named companies, all except Ash Grove and TXI were foreign owned as of yearend.

In 2005, output of portland cement increased by 1.6% to a new record of 93.9 Mt (table 3). The reported U.S. overall grinding (or cement) capacity and the capacity utilization percentage increased slightly, but the changes may not be statistically significant owing to issues of capacity data quality. The five leading producing States for portland cement in 2005 were, in descending order of tonnage produced, California, Texas, Pennsylvania, Florida, and Michigan. A majority of districts showed increased production levels. The increase in production in Florida was especially large, reflecting a full year of full capacity output by a plant that had completed a major upgrade in 2004. The large increase in Alabama appears related to a full year's output from a new finish mill installed in 2004 at one plant, and perhaps also the installation of a new clinker cooler at another. The large increase in output in Texas appears to be largely market driven. Elsewhere, the larger increases appear related to a combination of strong markets and technical upgrades at plants. District-level capacity utilization percentages did not change dramatically for most districts. The decline in output and in capacity utilization in the Georgia, Virginia, and West Virginia district appears to be mainly because of greatly reduced output by one plant, owing to the company servicing its customers from more modern plants elsewhere. The large decline in California overall is distributed among many of the plants and appears to be related to a combination of rising fuel costs and an increased availability of imported cement. Yearend stockpiles were up significantly, and this rise appears to reflect a combination of an increased availability of imported cement and disruptions to consumption related to hurricanes Katrina (end of August) and Rita (late September). However, the yearend sample is not indicative of the stockpile fluctuation throughout the year.

Data are not collected on the production of specific varieties of portland cement, but production levels would approximate the ratios among sales, by type, of portland cement (table 15). On this basis, production of Types I and II (or hybrids thereof) accounted for about 77% of total portland cement output in 2005, down from about 78% (revised) in 2004. This apparent relative decline, although small, reflects the growing market for sulfate-resistant cements (Types II and V; and II/V hybrids reported as Type V, and blended cements). Again by analogy to sales, Type V cements accounted for almost 15% of total output, compared with about 14% in 2004, and overall blended cement output was about 2.6% of the total portland cement production in 2005, compared with 1.6% in 2004. Ideally, these ratios should be adjusted for cement imports, which are dominantly of Types I, II, and V.

In 2005, masonry cement production increased by 8.3% to a record 5.4 Mt (table 4), reflecting the continued strong housing market. As in past years, however, this reported figure understates true output, primarily because a large, but unknown, tonnage of masonry cement (especially portland-lime cement) is directly blended at job sites using purchased portland cement and lime. Although not revealed in the tables, about 84% of the 2005 masonry cement production was reported as having been made directly from clinker rather than from finished portland cement. This was a significant decline from the 95% (from clinker) reported in 2004 and recent previous years, and the reason for this change (if not owing to assignation errors by respondents) is unclear.

Clinker production data are listed in table 5. Overall production during the year was a record 87.4 Mt; this, however, was an increase of only 0.9%. Although not apparent from table 5 (shows a single-year only), most districts showed only small changes in clinker output in 2005. Florida showed a significant increase, owing to a major upgrade at one plant the preceding year. A comparable upgrade in South Carolina in 2004 did not result in a large increase in clinker output in 2005 for the State because it was partly offset by production disruptions related to the upgrade of another plant in the State in 2005. A significant decline in production in the Georgia, Virginia, and West Virginia district was in-line with the 2004 closure of the kiln at one Georgia plant (it continued, however, to grind clinker brought in from another State). Other changes to the kiln counts were related to wet-to-dry technology changes (Florida, Maine,

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and South Carolina in 2004, and South Carolina in 2005). Because table 5 shows all kilns active for at least 1 day during the year, kiln closures during the current year will not show up until the next year. The closure at yearend of four kilns at one plant in eastern Pennsylvania is thus not visible on the current table.

As with the kiln count, changes to apparent annual capacity and capacity utilization are also affected by plant upgrades. Large apparent capacity declines, but increases in capacity utilization, in Florida and in the Maine and New York district in 2005 merely reflect the replacement of two wet kilns by a dry kiln in Florida in 2004, and the 2004 kiln conversion, and hence replacement of wet kiln capacity by dry capacity, at the plant in Maine. In contrast, the approximately 1.2-million-metric-ton-per-year (Mt/yr) increase in capacity, but very low capacity utilization, in 2005 in South Carolina reflects the replacement of four wet kilns with one dry kiln at one plant during the year; the State's capacity will decline in 2006 accordingly, and the capacity utilization would be expected to increase significantly.

Except for States having new plants, plant shutdowns, or plant upgrades during the current or preceding year, annual variations in district-level apparent annual capacities (a calculated statistic) and capacity utilization rates are difficult to analyze because the statistics are dependent on the reported daily kiln capacities and the correct reporting of kiln downtimes for scheduled maintenance relative to total downtimes. For example, southern California showed a significant (0.2 Mt) decline in clinker output in 2005 and about a 0.3-Mt decline in apparent annual capacity, yet there were no plant closures or significant upgrades during the year, and the overall daily clinker capacity and average days for routine maintenance are essentially identical to those of 2004. The apparent annual capacity decline is because of more days of routine maintenance at a couple of the larger facilities; however, the longer maintenance is invisible on the table because of offsets by shorter maintenance periods at other plants in the district. The apparent annual capacity for the country overall declined by 1 Mt/yr to 102 Mt; this mostly reflects the removal of "artificial" capacity related to kiln conversions. The average capacity utilization increased 2% to 86.0%, but the increase may not be statistically significant. Given that total downtimes commonly exceed the downtimes for routine maintenance, a capacity utilization of about 85% or higher indicates that the plants were operating at full practicable capacity; this was the case in all districts (as noted above, South Carolina's low utilization rate is artificial). Based on the data in table 5, the average plant clinker capacity in 2005 was significantly unchanged at about 0.96 Mt/yr, and average kiln capacity rose slightly to 0.56 Mt/yr.

Yearend clinker stockpiles were about 3.5 Mt, down about 0.2 Mt, but it is unclear if this represents an actual net "operational" drawdown of stocks[3] and hence a proportional increase in availability of clinker for cement manufacture. Including the significant increase in clinker imports in 2005 (table 21), this apparent stockpile drawdown would appear to be in excess of that needed to account for the increase in portland and masonry cement production during the year and, therefore, caution should be used in interpreting yearend stockpile changes.

Nonfuel raw materials consumed to make clinker and cement are listed in table 6. Materials used to make clinker are burned in the kiln and are thus of potential environmental interest. In contrast, materials added in the finish mill are just ground and are associated with only minor, if any, emissions. The total raw materials to make clinker did not change in 2005, and the ratios among raw materials (as contributors of major oxides) appear to be broadly similar to those in 2004. Some classes of raw materials—notably the aluminous, ferrous, and secondary material (for example, ashes and slags) siliceous feeds—appear to have increased in percentage terms much more than the total clinker production increased, but while it is tempting to treat these changes in terms of a single, closed, system (X went up because Y went down), in fact the changes in some of the materials reflect changes at just a few plants. The increases seen in the consumption of SCM (fly ash, GGBFS, natural pozzolans, and other pozzolans) for finished cement are in accord with increases in sales of blended cements (table 15) and increased production of masonry cement (table 4). This may also be true for cement kiln dust (CKD) for cement, although the increase could merely reflect more complete reporting. The increase in ground limestone used to make cement would appear largely to reflect the higher output of masonry cement in 2005 rather than the change to the ASTM C-150 portland cement standard noted earlier.

The tonnages of other blast furnace slag and steel slag consumed to make clinker are in broad accord with sales (to make clinker) collected on the USGS canvass of ferrous slag processors (air-cooled blast furnace slag sales of 0.15 Mt in 2004 and 0.37 Mt in 2005; steel slag sales of 0.50 Mt in 2004 and 0.60 Mt in 2005). A comparison cannot be made for GGBFS, because most of the material sold by slag processors went directly to the concrete industry rather than to cement plants. By comparison to the sales levels for blended cements listed in table 15, the proportion of GGBFS in cement appears to have fallen to about 28% (component) from about 35% in 2004. This decline could be real, or it could represent a change in the amount of slag used as a grinding aid (in straight portland cement) or an increase in the incorporation of slag into masonry cement.

Likewise, relative to sales, the apparent component of fly ash in blended cements was about 42% in 2005, compared with about 22% in 2004. This shift appears to be real. The total fly ash consumption listed in table 6 (3.10 Mt), and that of other ash (1.21 Mt), are significantly higher than the 2.57 Mt of fly ash, 0.85 Mt of bottom ash, and 0.04 Mt of boiler slag reported by the American Coal Ash Association (ACAA) as having been sold in 2005 for cement and/or raw feed for clinker (American Coal Ash Association, 2006); the same held true for 2004. Although the higher tonnages in table 6 could represent material already resident in cement plant raw material stockpiles (i.e., purchased prior to 2004-05), it may be that the ACAA survey contains some distribution problems between material sold to the cement industry itself and material sold to concrete companies, especially where the concrete companies are subsidiaries of cement companies. Within the gypsum consumption tonnages listed in table 6 are 0.29 Mt of synthetic gypsum (also known as flue gas

[3]Yearend stockpiles of clinker are an artifact of data collection convenience rather than a reflection of full-year market conditions or production capacity. Generally, if the clinker is not required for immediate cement market needs, a plant will try to build up its stocks of clinker prior to scheduled extended kiln shutdowns so as to provide continuity of clinker feed to the finish (cement) mill. These shutdowns can be at any time of the year.

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desulfurization or FGD gypsum) consumed in 2004 and 0.530 Mt in 2005; however, because the USGS canvass does not require a differentiation between natural and synthetic gypsum, these synthetic gypsum tonnages are likely understated. In contrast, the ACAA survey shows sales to the cement industry of 0.41 Mt of FGD gypsum in 2004 and 0.36 Mt in 2005. The higher tonnage within table 6 for 2005 may reflect material already in stock at cement plants, or it may reflect an increase in the number of cement plants having sulfur oxide scrubbing systems.

Fuels consumed by the cement industry are listed in table 7. The quantity ratios among fuels and of fuels to clinker produced in 2005 appear to be broadly similar to those in 2004; specific shifts may be owing to changes at just a few plants. Some of the changes in fuels relative to kiln technology reflect the conversion of certain wet kiln facilities to dry kiln technology (plants undergoing this conversion are considered to be combination plants for the conversion year [denoted as "Both" in table 7] and will be listed with the dry plants the subsequent year). For the industry overall, the only significant fuel change appears to be apparent offset of the large decline in fuel oil consumption by a large increase in the consumption of liquid waste fuels. This reflects the continuing high cost of petroleum, but may in part also reflect changes in categorization of "off-spec" fuel oil (a fairly common fuel).

Although not listed in table 7, overall heat consumption in 2005 was about 4.4 billion joules (GJ)[4] per metric ton of clinker, about 2% lower than in 2004. Wet plants in 2005 averaged about 6.3 GJ per ton of clinker, about 2% higher than in 2004. Dry kiln plants averaged about 4.1 GJ per ton of clinker, about 2% lower than in 2004, and combination plants averaged 4.9 GJ per ton, up by about 5%. The changes primarily reflect conversions of wet to dry kiln technology.

Dry process plants have higher average electricity consumption per ton of cement product than wet process plants (table 8). This reflects the complex array of fans and blowers associated with modern dry kilns and clinker coolers. Declines were seen in average unit electricity consumption for wet and dry plants in 2005, but the consumption average rose significantly for combination plants. These changes reflected the reassignment of two plants (in Florida and Maine), listed within "Both" for 2004, to the dry category for 2005, and the assignment of a South Carolina plant undergoing conversion to the "Both" category for 2005; it had been a wet plant in 2004. Abnormally high unit electricity consumption is common during such conversions. For the same general technology, plants operating multiple kilns almost invariably have higher electrical power (and general energy) requirements per ton of overall output capacity than do plants with the same overall capacity but that operate a single kiln.

There were no plant openings or closures during the year, although Essroc Cement Corp. permanently shut down the kilns at its Nazareth III plant in eastern Pennsylvania at yearend; the facility will continue to operate its finish mill (will be a grinding plant). The company's nearby integrated (clinker and cement) Nazareth I and II facilities remain fully operational.

[4]The USGS canvass solicits information on heat consumption in terms of millions of British thermal units (MBtu), where 1 MBtu=1.055056 GJ, and data are based on high or gross heat values of fuels rather than low or net heats.

Although not mentioned in the previous edition of this report nor incorporated in the current report's tables, it is of historical interest to note that there has been limited production of natural cement in the United States since 2004, when production was resumed from raw material quarried at Rosendale, NY. Natural cement was the first cement type to be produced in the United States (1817) and was for many decades in common production, but over the years it was superseded for concrete applications by portland and related cements. Many natural cement plants converted to portland cement production in the early 20th century, and the remaining natural cement production and sales data were included within the masonry cement category. Natural cement was produced at Rosendale during the period 1825-1970, at which time the company there, Century Cement Co., closed; Century had been the last producer in the country. The manufacture of natural cement differs from that of portland cement primarily in two ways. First, natural cement is made by burning only argillaceous limestones ("cement rock") and does not have the artificial mixing of raw materials in the kiln feed (limestone plus clay or shale, etc.) that is almost ubiquitous for portland cement. Second, the processing temperatures in the kiln are lower for natural cement (at least that made in the United States), such that sintering or clinkering does not occur and thus alite or tricalcium silicate (essentially the defining mineral in portland cement) is not formed. In natural cement, the hydraulic reactivity is mainly from a lower-temperature phase called belite or dicalcium silicate (this is also present in portland cement), and possibly heat-activated clay pozzolans. The resumption of natural cement production in 2004 was by Edison Coatings, Inc., which processes Rosendale, NY, cement rock at a small kiln in Plainville, CT. The natural cement is used, primarily, for the restoration of historical buildings originally constructed with natural cement concrete and/or mortar. For this restoration work, the hydration properties of natural cement mortars are considered to be more compatible than mortars incorporating portland-cement-base masonry cements or hydraulic lime (Edison Coatings Inc., 2006§). Although current output of natural cement by Edison is currently only a small fraction of the plant's kiln capacity of about 10,000 tons per year, demand for the product is anticipated to increase. To this end, the company was attempting to reinstate the ASTM C-10 standard for natural cement. This standard was initially adopted in 1904 but was withdrawn in 1974 owing to lack of product availability (Edison, 2006).

On March 1, CEMEX S.A. de C.V. of Monterrey, Mexico, announced that it had completed the purchase of the worldwide assets of RMC Group plc of the United Kingdom (CEMEX S.A. de C.V., 2005a). This purchase included the RMC Pacific Materials, Inc. cement plant in Davenport, CA, and a number of concrete plants, but had the main impact of making CEMEX one of the largest world producers of ready-mixed concrete. Peripherally related to the RMC acquisition, CEMEX announced in November an agreement to sell its Dixon, IL, and Charlevoix, MI, plants, together with a number of terminals servicing the Great Lakes region, to Votorantim Participacões S.A. of Brazil (The sale was completed in March 2005 (CEMEX S.A. de C.V., 2005b). The plants were to be operated under Votorantim's Canadian subsidiary St. Marys Cement, Inc., which already operated grinding plants in Detroit, MI, and

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Milwaukee, WI, and which was a 50% joint-venture partner in Suwannee American Cement Co. in Branford, FL.

In January, Lehigh Cement Co. announced the completion of its purchase from Buzzi Unicem of the remaining 50% of Glens Falls Lehigh Cement Co. that Lehigh did not already own (Lehigh Cement Co., 2005). The purchase involved an integrated plant at Glens Falls, NY, and the Cementon grinding plant near Catskill, NY.

In May, Titan America formally inaugurated its new 1.8-Mt/yr dry kiln line at the Pennsuco integrated plant at Medley, FL. The new kiln had been first fired up in mid-2004 and replaced the plant's two wet kiln lines, which were shut later that year (Cement Americas, 2005b).

Following an April denial of a final permit related to waterborne shipping, St. Lawrence Cement Co. (the Canadian subsidiary of Holcim Group of Switzerland) announced that it had abandoned plans to build a 2-Mt/yr greenfields cement plant at Greenport, NY, on a site where the company already operated a large crushed stone quarry. The proposal to build a state-of-the art precalciner kiln plant at the Greenport plant had met with extended local environmental opposition, notwithstanding that it would have replaced the company's very old existing 0.7-Mt/yr wet kiln plant at Catskill, NY (Cement Americas, 2005c).

In March, Eagle Materials Inc. announced plans to upgrade its LaSalle, IL, cement plant through the installation of a precalciner onto its existing preheater kiln. The upgrade will raise the plant's clinker capacity by about 65% to 1.1 Mt/yr. The upgrade was expected to be completed at yearend 2006 (KHD Humboldt Wedag, Inc., 2005).

Giant Cement commissioned its new 1.1-Mt/yr precalciner kiln at Harleyville, SC, at the end of May. The new kiln replaced four wet kilns, totaling about 0.7 Mt/yr, which were permanently shut down during the year (World Cement, 2005).

Buzzi Unicem USA announced in December that it would upgrade its Selma, MO, plant by building a 2.3-Mt/yr precalciner kiln to replace the plant's existing long dry kilns (total capacity 1.3 Mt/yr). It was anticipated that the increased capacity would allow the company to reduce its imports of cement to supply customers along the Mississippi River (Buzzi Unicem SpA, 2005).

Monarch Cement Co. was nearing the completion of its project to install a precalciner on an existing kiln at its Humboldt, KS, plant, which will make that kiln identical in capacity to the company's other kiln, which was similarly upgraded in 2001. The upgrade was expected to be completed in March 2006, and would raise the plant's total capacity to about 1.1 Mt/yr (International Cement Review, 2005).

Texas Industries Inc. announced in April that it would modernize and expand its Oro Grande, CA, plant. The upgrade would replace the plant's existing 7 long dry kilns (total capacity about 1.2 Mt/yr of clinker) with a single precalciner dry kiln of about 2.1 Mt/yr capacity (Texas Industries, Inc., 2005). Currently, the Oro Grande plant produces an excess of clinker, which it then grinds at the company's Crestmore, CA, plant.

Consumption

Apparent consumption of portland and masonry cement rose 5.2% to about 128.3 Mt in 2005 (table 1). Because the data are available monthly from the USGS and show breakouts by State, the measure of consumption preferred by the cement industry for market analysis is that of cement shipments to final domestic customers (that is, sales). The full year summations of the monthly data are provided in table 9. The definition of "final customer" is left to the reporting cement producer but is generally understood to include the customer categories listed in table 14. Consumption measured as sales to final domestic customers increased in 2005 by 5.6% to a record 126.9 Mt.

In some years, significant differences have existed between the U.S. total portland cement sales amounts derived from annual canvasses, as listed in tables 1, 10-11, and 14-16, and the monthly-survey-based totals listed in table 9. The differences likely pertain to shipments (mainly of imported cement) by terminals that were missed by the annual survey but which were captured on the monthly surveys; the monthly surveys contain a lot of data submitted on a company-total rather than site-total basis. Owing to more complete annual canvassing, the tonnage differences for the past 5 years have became insignificant except for 2003 (1.7 Mt). In contrast to portland cement, data for masonry cement have not shown significant discrepancies between the monthly and annual reporting because little of this material is imported.

Superficial similarities between the national totals in table 9 and tables 12-13 hide important differences in their component data. Table 9 reveals the sales destinations and so directly provides the location and amounts of consumption. In contrast, the regional data in tables 11, 12, and 14 pertain to the location of the reporting entity (chiefly the production sites), not the location of consumption. It is very common for shipments to cross State lines.

Based on table 9, domestic portland cement consumption increased by 5.5% to a record 121.4 Mt in 2005 and would likely have been significantly higher had there not been severe disruptions to construction work caused by hurricanes Dennis (July), Katrina (August), Rita (September), and Wilma (October); Katrina also caused severe damage to ship unloading and general transportation infrastructure. Notwithstanding the hurricanes, the only individual months that showed declines in 2005 relative to 2004 were April (minor decline) and July (almost always a weak month). The import component of sales was about 23% of the total in 2005 compared with about 19% in 2004. Only about 11 States had significant declines in consumption in 2005 and almost all major consuming States showed large increases, including those impacted by the hurricanes. The leading 10 consuming States in 2005 were, in descending order, California, Texas, Florida, Arizona, Georgia, Illinois, Ohio, Pennsylvania, New York, and Michigan. The leading 5 States accounted for about 41% of total U.S. consumption, and the leading 10 States accounted for about 56% of the total.

Cement is a key construction material, and although cement consumption levels within a given category of construction will broadly reflect levels of construction spending, significant time lags may exist between the onset or cutoff of spending and changes in the consumption of cement or concrete. Lag times are particularly noticeable in sectors involving individual projects requiring high tonnages of concrete (for example, large office buildings, shopping complexes, and major public sector projects). According to U.S. Census Bureau data quoted by

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the Portland Cement Association (2006), overall construction spending levels in 2005 rose by 4.2% to about $755 billion (constant 1996 dollars). As in 2004, this increase was dominated by an increase in overall residential building construction ($424 billion, up by 7.2%), which in turn continued to dominated largely by an increase in single-family housing ($286 billion, up by 8.2%). This spending reflected continued very low mortgage and general interest rates. Nonresidential private construction spending overall reversed a multiyear declining trend by increasing 2.9% to $131 billion; this was led by industrial buildings (up by 23% to $20.4 billion) and office buildings (up by 3.2% to $29.3 billion). Educational and religious buildings were among the few declines during the year, but both are categories of construction that might be expected to show a significant time lag behind housing construction. Public sector construction was about the same as in 2004, $163 billion, and was dominated by buildings ($72.4 billion, down by 1.9%), and roads ($43.4 billion, up by 2.8%); these categories had shown significant spending declines in 2004.

Some of the spending shifts do not accord well with the breakout of portland cement sales by customer type listed in table 14. Sales tonnages to ready-mixed concrete companies (which engage in many types of concrete construction) were up 7.8% in 2005 and sales overall to contractors (a category that tends to overlap ready-mixed concrete) were slightly up (0.5%). Within a 3.7% overall increase in sales to makers of concrete products were declines in sales for brick and block manufacture (down 1.1%) and pipe manufacture (down by 7.3%); at least the brick and block decline would be in contrast to the single-family residential spending increase noted earlier. On the other hand, sales to precast-prestressed product manufacturers were up 5.9%, which would be in accord with the increased spending for private sector nonresidential buildings. However, the miscellaneous and/or unspecified component of concrete product sales went up by 12.6%, and this could indicate less precise reporting in 2005. Among sales to contractors, airport construction tonnages went up by almost 21% in 2005. Sales to road paving companies declined 8.4%, a surprise given the spending level increases noted above, but the tonnage decline could be at least partly because of overlap with the ready-mixed concrete category (which increased). An almost 53% increase in sales tonnages to "Government and miscellaneous" customers may reflect increases in security and military spending. High prices for many metals and for crude petroleum and natural gas during the year spurred increased drilling and mining activity, which were reflected in the 2.8% increase in sales tonnages for "oil well" drilling and the almost 26% increase in sales to the mining industry.

At least some of the poor correlation between overall construction spending and cement consumption levels could be owing to lag times or to changes in use of concrete relative to competing construction materials. For example, increases in the number and average size of new homes being built would be expected to result in more concrete for house foundations, but might not translate to commensurate increases in brick and block consumption if the houses are being constructed of wallboard and plywood, and have vinyl siding, or if it is clay brick being used instead of concrete brick. Single-family construction use of brick and blocks might be especially sensitive to large cement price increases, such as in 2005 (tables 11-13). Overall, the effect of competing materials can be crudely evaluated through use of a calculated "penetration rate" for cement. This can be defined as the tonnage of cement consumed per $1 million in spending and ideally should be done for each type of construction. Changes in penetration rates can reflect cost or performance advantages of concrete over competing construction materials, the specific sizes and types of construction projects, promotional efforts by the concrete industry, shifts in spending between new construction and repairs to existing infrastructure, lag times between construction spending and concrete consumption, and total cement consumption underreported because of partial substitution in concrete mixes of portland cement by other cementitious materials. Using the apparent consumption data in table 1, the overall construction spending data (revised for 2001-04) show a generally increasing trend in penetration rates for 2001–05; $1 million in construction spending bought, in chronological order, about 158 t of cement in 2001; 156 t in 2002; 162 t in 2003; 169 t in 2004; and 170 t in 2005.

Sales to final customers of different types of portland cement are listed in table 15. As in past years, Types I and II cement were dominant, but their relative dominance was declining somewhat in favor of sulfate-resistant varieties of cement (Type V, Type II/V hybrids reported as Type V, and some blended cements). Sales of oil well cements rose by almost 10%, although understate the market somewhat because shallow wells can sometimes be handled with less specialized cements. Blended cement sales were up strongly (almost 70%), especially those varieties containing fly ash; indeed, 2005 was the first year in which blended cement sales exceeded 3 Mt (the USGS monthly data for blended cements suggest that sales were actually about 2.96 Mt, however). The higher sales of blended cement would appear to reflect success in promotional efforts by the cement industry and environmental agencies to gain acceptance for these cements, especially for public sector construction projects, both in environmental terms and in terms of overall concrete strength and durability.

Portland cement shipments by method of transportation are listed in table 10. These data are prone to more reporting errors by survey respondents than most other forms of data, and thus small changes year-to-year may not be real. It is clear from this table that the U.S. market is a bulk cement market. As in past years, truck transportation was by far the dominant form of cement shipping to customers in 2005. The significant drop in overall initial shipments from plant to terminal in 2005 (column 1 of table 10) probably reflects an increased availability of imported cement to the terminals. The reduction in shipments by rail and by barge in this column may also reflect hurricane damage to ship unloading and transfer facilities (particularly in the New Orleans customs district), and to rail infrastructure.

Consumption of masonry cement rose 6.1% to a record 5.5 Mt; this is in accord with the strong housing construction market (table 9). However, given the decline in sales of block cement or sales of portland cement to brick and block makers noted above, the strong masonry cement sales would suggest that clay brick was capturing most of the masonry market related to housing.

Data on the mill net values for shipments to final customers by plants and import terminals (terminal nets) are listed in tables 11-13. Except to differentiate overall gray from white portland cement sales, respondents to the USGS annual canvass do not

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provide value data broken out by the specific varieties of portland cement sold. Both gray and white sales are included in table 11 and only table 13 provides a white cement value breakout (for the national average). The value data make no distinction between bulk and container (bag or package) shipments; however, container shipments would be expected to have higher unit values. The average mill net value of portland cement in 2005 was about $89.00 per metric ton, up by about $11.00 per ton. The magnitude of the increase in 2005 reflects a combination of cement shortages in 2004-05 and the smaller than expected price increase in 2004 owing to the existence of yearlong contracts. Many of these contracts appear to have been renegotiated in 2005, with the result that many of the reported valuations in 2005 incorporate, in effect, 2 years of price increases. The average mill net for masonry cement rose $9.50 per ton (table 12 and 13), but the amount of the increase should be viewed with caution because the data include a significant component of estimates, and some respondents reported values apparently exclusive of bagging or packaging charges (they are supposed to be included).

The unit values in tables 11 and 12 are free on board (f.o.b.) the plant. A crude estimate of delivery costs to the customer can be made by comparison to the U.S. 20-city average delivered cement prices (for Type-I portland and masonry cements) reported monthly by the journal Engineering News-Record (ENR). For 2005, the average ENR price for Type I portland cement, converted to metric units, was $96.72 per ton, up by only $3.90 per ton. By comparison, the average mill net for gray portland cement was $88.50 per ton, up by $11.50 per ton (table 13). Not only was the ENR price increase surprisingly modest, it suggests a delivery charge component of only $8.22 per ton in 2005, compared with an apparent delivery charge component of $15 per ton in 2004. In the face of very high fuel costs in 2005, it is highly unlikely that delivery charges actually decreased. The ENR price for concrete averaged $84.00 per cubic yard, up by about $6.50 per cubic yard. The ENR price for masonry cement calculates to about $182 per ton, up by about $7 per ton. The large difference between this and the average mill net value (table 13) for masonry appears to incorporate a variety of handling charges for this mainly bagged commodity.

Foreign Trade

Trade data from the U.S. Census Bureau are listed in tables 16-21. Exports of hydraulic cement and clinker increased slightly in 2005 but, except for sales to Canada, remained insignificant (tables 1, 16). Almost all of the exported material was cement. Overall imports of hydraulic cement and clinker in 2005 increased dramatically to a record 33.3 Mt, up 23.1% (table 17) and 13.3% higher than the previous record of 29.4 Mt in 1999. The cement component of these imports (table 17 data minus the clinker data in table 21) increased by an apparent 19.7% to 30.4 Mt, also a new record, and the apparent clinker component of imports increased by 75.3% to 2.9 Mt (table 21). The use of the "apparent" qualifier is deliberate because the trade data for 2003-05 and for an unknown number of recent previous years are incomplete with regards to overland imports from Canada, as discussed below. The clinker data for 2002 and later years have been manually corrected to remove any "clinker" coming into the Honolulu, HI, district; the material was actually gray portland cement incorrectly registered with the tariff code for clinker. The Honolulu data have been transferred to table 20 (gray portland cement).

The data for clinker, and possibly also for cement, imports from Canada are incomplete. For clinker, the official trade data show insufficient clinker from Canada coming into the Detroit, MI; Milwaukee, WI; and Seattle, WA, customs districts to feed the grinding plants that are located in Michigan, Wisconsin, and Washington, respectively. These plants are essentially reliant on Canadian (and, for the Detroit district in 2004-05, Brazilian) clinker and do not purchase significant quantities of domestic clinker. The unreported Canadian clinker appears to be either material that has been given a tariff code for portland cement by mistake by the importer or is clinker coming in by truck, including material that may be transshipped after truck entry into the United States. Because the individual truckloads are worth less than $2,000 (customs value), the shipments are classified as "informal entries," and data on them are not routinely transmitted by the U.S. Customs Service to the U.S. Census Bureau for recordation into the official trade data (reproduced in tables 17-21). This recordation problem presumably does not exist for imports by rail or by barge or ship because these shipments are larger. Clinker imports from Canada have been estimated to be higher than those reported by about 0.6 Mt in 2004 and about 0.5 Mt in 2005 (tables 1, 21). Likewise, certain U.S. cement companies with plants in Canada near the U.S. border may allow some of their U.S. final customers to pick up cement at the Canadian plants. Although these sales, as listed in table 9, are being recorded correctly in the companies' monthly reporting to the USGS, an informal entry data recordation problem could exist for individual truckloads worth less than $2,000; this, however, is unlikely to have been an issue in 2005 because of the much higher cement prices. Given the large volumes of Canadian cement that do get recorded by the U.S. Census Bureau and the fact that the USGS monthly canvass form cannot distinguish the mode of entry of imported cement, the magnitude of the underreporting of cement imports in past years from Canada is difficult to estimate.

The 10 busiest customs districts of entry in 2005 were, in descending order, New Orleans, LA; Tampa, FL; Los Angeles, CA; Houston-Galveston, TX; San Francisco, CA; Miami, FL; Seattle, WA; Detroit, MI; New York, NY; and Charleston, SC (table 18). The 10 leading country suppliers of cement and clinker in 2005 were, in descending order, Canada, China, Thailand, Greece, the Republic of Korea, Venezuela, Mexico, Colombia, Taiwan, and Sweden. The largest increase in imports was from China, up by 2.6 Mt or 123%, but very large tonnage (and percentage) increases were also seen for Greece, Mexico, the Republic of Korea, Peru, and Taiwan. The imports from Asian countries were of especial interest because whereas they once were mainly into Pacific coast ports, they now are heavily present on the Gulf and Atlantic coasts as well. Imports from Mexico were up by 52% from those of 2004, which in turn were up 60% from those of 2003, and the increases were despite ongoing antidumping tariffs.

White cement import data are listed in table 20. Although no attempt has been made to correct the data, it is evident that a few

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of the country entries, notably entries for Brazil, the Dominican Republic, Greece (2005 only), Switzerland, and Venezuela, have unit values that are too low to be white cement. It is likely that this relatively inexpensive material is actually gray portland cement or even gray clinker for which a white cement tariff code was recorded by the importer. Some other entries have values that seem slightly low, and these may contain a component of gray portland cement.

Owing to fuel cost increases and some shortages of ships, there were widespread reports in 2004 of substantially higher fuel-related shipping costs for imports as well as steep rises in the chartering rates for cement ships and other bulk carriers. Chartering rates were said to have been mixed in 2005, but ship availability much improved. The difference between the unit customs value and that on a cost, insurance, freight (c.i.f.) basis is a proxy for the shipping cost. For imported gray portland cement in 2004, this difference was $19.66 per ton (up by more than 50% from that in 2003), after deducting the imports (all or mostly overland) from Canada and Mexico. For 2005, the calculation yields a difference of $24.00 per ton, up by 22%. The average c.i.f. price for waterborne imports in 2005 was $67.51 per ton, up 17.7% and the average Customs value was $43.51, up 15.4%. Shipping costs as a percentage of the c.i.f. price averaged 35.6% for waterborne imports in 2005, against 34.3% in 2004.

World Review

World hydraulic cement production data are listed in table 22. Although the data are supposed to include all forms of hydraulic cement, the data for the United States are for portland plus masonry cement only, and the data for some other countries also may be incomplete. The data for some countries may include their exports of clinker.

World cement production increased by about 5% in 2005 to an estimated 2.3 Gt. More than 150 countries produced cement during the year; production was very unevenly distributed. China was once again the overwhelmingly largest producer, with an output for the first time exceeding 1 Gt; this was almost 45% of world output. The large increase in its exports to the United States was only part of a significant rise in total Chinese cement exports; China has become the world's leading cement exporter. The remaining top 15 producing countries were, in descending order, India, the United States, Japan, the Republic of Korea, Spain, Russia, Italy, Turkey, Thailand, Indonesia, Brazil, Mexico, Iran, and Germany. Cumulatively, the top 5 countries had about 61% of total world output; the top 10 countries, about 70%; and the top 15 countries, about 78%.

Regionally, Asia contributed about 65% of world production and included 6 of the 15 leading producing countries. Western Europe had about 9% of total output; North America, about 7%; the Middle East (including Turkey), about 6%; Central America and South America, about 4%; Africa, about 4%; the Commonwealth of Independent States, about 3%; and Eastern Europe, 2%.

Outlook

Interest (including mortgage) rates were expected to rise in 2006, and this was expected to have a significant negative impact on private sector construction, particularly for single-family housing. Because of the work disruptions and damage caused by the hurricanes (especially Katrina) in 2005, repair and catch up construction activity in at least the first quarter of 2006 was expected to be very high, and thus offset some of the housing construction decline in terms of cement consumption. Public sector construction spending, including that for transportation infrastructure, was expected to increase, but the degree was uncertain, including the ultimate degree of repair and restoration activity in the hurricane damaged regions. Overall, cement consumption in 2006 was expected to be 1% to 3% higher than that in 2005, absent unusually severe weather conditions. Although a number of companies had announced capacity expansion plans, this activity was not expected to contribute to clinker production in 2006 by very much, and so import levels were expected to increase to meet any excess demand. Ultimately, increased production capacity was expected to reduce the need for imports in the medium- to long-term. It appeared likely that import duties on imported Mexican cement would be significantly reduced in 2006, but it was unclear to what extent this would result in higher short-term imports (largely brought in by rail) from Mexico, given the already strong increases in imports from Mexico in 2004-05 and the U.S. rail infrastructure having little extra capacity. In any case, it was unlikely that increased Mexican imports would penetrate very far into the United States and so would not significantly alleviate cement shortages in most States.

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TABLE 1
SALIENT CEMENT STATISTICS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

	2001	2002	2003	2004	2005
United States:[2]					
Production:					
Cement[3]	88,900	89,732	92,843	97,434	99,319
Clinker	78,451	81,517	81,882	86,658	87,405
Shipments from mills and terminals:[4,5]					
Quantity	112,510	108,500	111,000	120,000	127,000
Value[6]	8,600,000	8,250,000	8,340,000	9,520,000 r	11,600,000
Average value[7] dollars per metric ton	76.50	76.00	75.00	79.50	91.00
Stocks at mills and terminals, yearend	6,600	7,680	6,610	6,710	7,390
Exports of cement and clinker	746	834	837	749 r	766
Imports for consumption:					
Cement[8]	23,694	22,198	21,015	25,396	30,403
Clinker	1,782	1,603	1,808	1,630	2,858
Total[9]	25,474	23,801	22,823	27,026	33,261
Consumption, apparent[10]	112,810	110,020	114,090	121,980 r	128,280
World, production[e, 11]	1,740,000 r	1,850,000	2,030,000 r	2,190,000 r	2,310,000

eEstimated. rRevised.

[1]Unless otherwise indicated, data are for portland (including blended) and masonry cements only. Even where presented unrounded, data are thought to be accurate to no more than three significant digits.

[2]Excludes Puerto Rico.

[3]Includes cement produced from imported clinker.

[4]Includes imported cement and cement made from imported clinker. Includes sales by import terminals.

[5]Shipments to final domestic customers. Data are from an annual survey of plants and terminals and may differ from the totals in table 9, which are based on consolidated monthly surveys from companies.

[6]Value at mill or import terminal of cement shipments to final domestic customers.

[7]Total value at mill or import terminal divided by the total tonnage sold.

[8]All forms of hydraulic cement or clinker, respectively.

[9]Data may not add to totals shown because of independent rounding.

[10]Production (including that from imported clinker) of portland and masonry cement plus imports of hydraulic cement minus exports of cement minus change in yearend cement stocks.

[11]Total hydraulic cement. May include clinker exports for some countries.

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TABLE 2
COUNTY BASIS OF SUBDIVISION OF STATES IN CEMENT TABLES

State subdivision	Defining counties
California, northern	Alpine, Fresno, Kings, Madera, Mariposa, Monterey, Tulare, Tuolumne, and all counties farther north.
California, southern	Inyo, Kern, Mono, San Luis Obispo, and all counties farther south.
Chicago, metropolitan	Cook, DuPage, Kane, Kendall, Lake, McHenry, and Will Counties in Illinois.
Illinois	All counties other than those in metropolitan Chicago.
New York, eastern	Delaware, Franklin, Hamilton, Herkimer, Otsego, and all counties farther east and south, excepting those within Metropolitan New York.
New York, western	Broome, Chenango, Lewis, Madison, Oneida, St. Lawrence, and all counties farther west.
New York, metropolitan	New York City (Bronx, Kings, New York, Queens, and Richmond), Nassau, Rockland, Suffolk, and Westchester.
Pennsylvania, eastern	Adams, Cumberland, Juniata, Lycoming, Mifflin, Perry, Tioga, Union, and all counties farther east.
Pennsylvania, western	Centre, Clinton, Franklin, Huntingdon, Potter, and all counties farther west.
Texas, northern	Angelina, Bell, Concho, Crane, Culberson, El Paso, Falls, Houston, Hudspeth, Irion, Lampasas, Leon, Limestone, McCulloch, Reeves, Reagan, Sabine, San Augustine, San Saba, Tom Green, Trinity, Upton, Ward, and all counties farther north.
Texas, southern	Brazos, Burnet, Crockett, Jasper, Jeff Davis, Llano, Madison, Mason, Menard, Milam, Newton, Pecos, Polk, Robertson, San Jacinto, Schleicher, Tyler, Walker, Williamson, and all counties farther south.

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TABLE 3

PORTLAND CEMENT PRODUCTION, CAPACITY, AND STOCKS IN THE UNITED STATES, BY DISTRICT[1]

	2004					2005				
			Capacity[2]					Capacity[2]		
District[5]	Active plants	Production[3] (thousand metric tons)	Finish grinding (thousand metric tons)	Percentage utilized[6]	Stocks at yearend[4] (thousand metric tons)	Active plants	Production[3] (thousand metric tons)	Finish grinding (thousand metric tons)	Percentage utilized[6]	Stocks at yearend[4] (thousand metric tons)
Maine and New York	5	3,266	4,569	71.5	167	5	3,241	4,569	70.9	220
Pennsylvania, eastern[7]	7	4,706	5,378	87.5	209 [8]	7	4,715	5,410	87.2	270
Pennsylvania, western	3	1,522	1,704	89.3	105 [8]	3	1,573	1,719	91.5	126 [8]
Illinois	4	3,009	3,388	88.8	263	4	3,237	3,410 [8]	95.0	199 [8]
Indiana	4	3,077	3,723	82.6	253	4	3,058	3,723	82.2	223
Michigan and Wisconsin[9]	6	5,688	7,363	77.3	283	6	5,599	7,330 [8]	76.4	323 [8]
Ohio	2	1,020	1,333	76.6	49	2	986	1,333	74.0	57
Iowa, Nebraska, South Dakota	5	4,257	6,064	70.2	346	5	4,502	6,062	74.3	392
Kansas	4	2,687	3,042	88.3	196	4	2,887	3,110 [8]	92.8	146
Missouri	5	5,263	6,822	77.1	471	5	5,332	7,017	76.0	444
Florida[7]	7	5,232	7,370 [8]	71.0	420	7	5,726	7,301	78.4	537 [8]
Georgia, Virginia, West Virginia	4	2,832	3,847	73.6	168	4	2,370	3,440 [8]	68.9	268
Maryland	3	2,519	2,706	93.1	164	3	2,552	2,706	94.3	146
South Carolina	3	3,114	4,587	67.9	272	3	3,267	5,018	65.1	185
Alabama	5	4,796	5,173	92.7	299	5	5,123	5,948	86.1	270
Kentucky, Mississippi, Tennessee	4	3,232	3,587	90.1	335 [8]	4	3,311	3,679	90.0	304
Arkansas and Oklahoma	4	2,753	3,277	84.0	253	4	2,810	3,280 [8]	85.6	128
Texas, northern[7]	6	6,393	7,400 [8]	86.3	322	6	6,639	7,560 [8]	87.8	803
Texas, southern	5	4,791	5,534	86.6	214 [8]	5	4,916	5,620 [8]	87.5	211
Arizona and New Mexico	3	2,750	3,477	79.1	98	3	2,788	3,480 [8]	80.2	106
Colorado and Wyoming	3	2,706	3,281	82.5	146	3	2,648	3,025	87.5	185
Idaho, Montana, Nevada, Utah	6	2,973	3,770 [8]	78.9	180	6	3,085	3,740 [8]	82.6	203
Alaska and Hawaii	--	--	--	--	65	--	--	--	--	71
California, northern	3	2,656	2,944	90.2	153	3	2,696	2,944	91.6	127 [8]
California, southern[7]	8	9,272	10,500 [8]	88.4	331	8	8,868	10,200 [8]	86.6	217 [8]
Oregon and Washington	4	1,921	2,390	80.4	189 [8]	4	1,974	2,448	80.6	163
Independent importers, n.e.c.[9]	--	--	--	--	315 [8]	--	--	--	--	528 [8]
Total or average[10]	113	92,434	113,000 [8]	81.6	6,270 [8]	113	93,904	114,000 [8]	82.3	6,850 [8]
Puerto Rico	2	1,580	2,462	64.2	43	2	1,584	2,462	64.3	45
Grand total or average[10]	115	94,014	116,000 [8]	81.3	6,310 [8]	115	95,488	117,000 [8]	81.9	6,900 [8]

-- Zero.

[1]Even when presented unrounded, data are thought to be accurate to no more than three significant digits. Includes data for white cement.

[2]Reported grinding capacity is based on fineness needed to produce a plant's normal product mix, including masonry cement, and allowing for downtime for routine maintenance.

[3]Includes cement produced from imported clinker.

[4]Includes imported cement. Includes mills and terminals.

[5]District assignation is the location of the reporting facilities. Includes independent importers for which regional assignations were possible.

[6]Calculated relative to portland cement output.

[7]Data, except for stockpiles, exclude one plant that reported cement (clinker) grinding capacity but reported no production of portland cement.

[8]Data contain estimates for nonrespondent or incompletely reporting facilities.

[9]Not elsewhere classified. Data include only those importers or terminals for which regional assignations were not possible.

[10]Data may not add to totals shown because of independent rounding.

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TABLE 4

MASONRY CEMENT PRODUCTION AND STOCKS IN THE UNITED STATES, BY DISTRICT[1]

	2004			2005		
District[4]	Active plants	Production[2] (thousand metric tons)	Stocks at yearend[3] (thousand metric tons)	Active plants	Production[2] (thousand metric tons)	Stocks at yearend[3] (thousand metric tons)
Maine and New York	4	127	20	4	119	18
Pennsylvania, eastern	6	289	37	6	399 [5]	60 [5,6]
Pennsylvania, western	3	W	W	3	W [5]	W [5]
Indiana	4	W	W	4	555 [7]	72 [7]
Michigan	4	231	32	4	228	46 [5,6]
Ohio	2	98	18	2	W [7]	W [7]
Iowa, Nebraska, South Dakota	2	W	W	2	W	W
Kansas	2	W	W	2	W	W
Missouri	1	W	W	2	W	W
Florida	5	763	45	5	902	35
Georgia, Virginia, West Virginia	5	419	49	5	543 [8]	51 [8]
Maryland	2	W	W	2	W [8]	W [8]
South Carolina	3	453	7	3	498	26
Alabama	4	430	56	4	475	77
Kentucky, Mississippi, Tennessee	3	W	W	3	W	W
Arkansas and Oklahoma	4	161	15	4	188	18
Texas, northern	4	161	22	5	213	21
Texas, southern	3	158	5 [6]	3	182	13
Arizona and New Mexico	3	W	W	3	W	W
Colorado and Wyoming	2	W	W	2	W	W
Idaho, Montana, Nevada, Utah	--	W	W	1	W	W
Alaska and Hawaii	--	--	--	--	--	--
California, northern	3	81	6	3	67	11
California, southern	4	605	12	4	627	12
Independent importers, n.e.c.[9]	--	--	5 [6]	--	--	4 [6]
Total[10]	73	5,000	441 [6]	76	5,415	532 [6]

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.

[1]Includes masonry, portland-lime, and plastic cements. Even where presented unrounded, data are thought to be accurate to no more than three significant digits.

[2]Includes cement produced from imported clinker.

[3]Includes imported cement.

[4]District assignation is the location of the reporting facilities. Includes independent importers for which regional assignations were possible.

[5]For 2005, western Pennsylvania tonnages are included with eastern Pennsylvania.

[6]Data contain estimates for nonrespondent or incompletely reporting facilities.

[7]For 2005, Ohio tonnages are included with Indiana.

[8]For 2005, Maryland tonnages are included with Georgia, Virginia, and West Virginia.

[9]Not elsewhere classified.

[10]Data may not add to totals shown because of independent rounding.

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TABLE 5

CLINKER CAPACITY AND PRODUCTION IN THE UNITED STATES IN 2005, BY DISTRICT[1]

District	Active plants[2] Process used Wet	Dry	Both	Total	Number of kilns[6]	Daily capacity[3] (thousand metric tons)	Average days of routine maintenance	Apparent annual capacity[4] (thousand metric tons)	Production (thousand metric tons)	Percentage of capacity utilized	Yearend stocks[5] (thousand metric tons)
Maine and New York	2	2	--	4	5	10.9 [7]	26.6	3,670 [7]	3,072	83.6 [7]	85
Pennsylvania, eastern	2	5	--	7	14	16.3 [7]	24.1	5,430 [7]	4,501	82.9 [7]	177
Pennsylvania, western	2	1	--	3	7	5.2	19.6 [7]	1,800 [7]	1,553	86.1 [7]	48
Illinois	--	4	--	4	8	8.6	14.5	2,980	2,721	91.4	148
Indiana[8]	1	3	--	4	8	10.6	21.1	3,640	3,161	86.8	115
Michigan	1	2	--	3	8	14.2	26.6	4,810	4,111	85.5	443 [7]
Ohio	1	1	--	2	3	3.4	18.3	1,190	1,010	84.7	71
Iowa, Nebraska, South Dakota	--	4	1	5	9	14.0	20.8	4,790	4,093	85.5	173
Kansas	1	3	--	4	9	9.0	20.0	3,130	2,792	89.1	97
Missouri	2	3	--	5	6	15.9	21.1	5,400	4,871	90.3	137
Florida	--	6	--	6	7	18.0	21.7	6,150	5,285	85.9	199
Georgia, Virginia, West Virginia	1	2	--	3	5	8.4	18.6 [7]	2,870 [7]	2,245	78.4 [7]	131
Maryland	1	2	--	3	4	8.1	18.3	2,760	2,458	89.1	79
South Carolina	--	2	1	3	7	14.3	18.4	4,880	3,147	64.5	163
Alabama	--	5	--	5	5	16.6	23.4	5,630	4,884	86.7	82
Kentucky, Mississippi, Tennessee	1	3	--	4	4	10.3 [7]	16.8	3,580 [7]	3,133	87.4 [7]	175
Arkansas and Oklahoma	2	2	--	4	10	8.3	15.7	2,890	2,628	90.9	62
Texas, northern	2	3	1	6	16	20.9	16.5	7,250	6,363	87.8	262
Texas, southern	--	4	1	5	6	13.9	17.4	4,830	4,385	90.8	199
Arizona and New Mexico	--	3	--	3	7	8.6	21.3	2,990	2,604	87.0	91
Colorado and Wyoming	--	3	--	3	4	8.9	19.3	3,030	2,409	79.5	56
Idaho, Montana, Nevada, Utah	3	3	--	6	8	8.4	15.2	2,930	2,797	95.5	24
California, northern	--	3	--	3	3	8.8	18.6	3,060	2,593	84.7	114
California, southern	--	8	--	8	17	29.4	23.2	9,860	8,873	90.0	352
Oregon and Washington	1	2	--	3	3	6.3	36.3	2,060	1,715	83.3	33
Total or average[9]	23	79	4	106	183	297.2 [7]	21.7 [7]	102,000 [7]	87,405	86.0 [7]	3,520 [7]
Puerto Rico	--	2	--	2	2	5.9	21.0 [7]	2,020 [7]	1,378	68.4 [7]	64
Grand total or average[9]	23	81	4	108	185	303.1 [7]	21.7 [7]	104,000 [7]	88,783	85.7 [7]	3,580 [7]

-- Zero.

[1]Even where presented unrounded, data are thought to be accurate to no more than three significant digits.

[2]Includes white cement plants. Includes all plants active for at least one day during the year.

[3]Sum of reported daily kiln capacities for each plant in district.

[4]Sum of apparent annual kiln capacities; for each kiln calculated as 365 days (366 in leap years) minus days reported as shut down for routine maintenance and then multiplied by the reported (unrounded) daily capacity.

[5]Includes imported clinker and clinker stockpiles at grinding plants.

[6]Kilns active at least one day during year. Excludes idle kilns (full year) that cannot be restarted, fully permitted, in less than 6 months.

[7]Data contain estimates for nonrespondent or incompletely reporting facilities.

[8]Includes one semidry kiln.

[9]Data may not add to totals shown because of independent rounding.

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TABLE 6

RAW MATERIALS USED IN PRODUCING CLINKER AND CEMENT IN THE UNITED STATES[1, 2]

(Thousand metric tons)

Raw materials	2004		2005	
	Clinker	Cement[3]	Clinker	Cement[3]
Calcareous:				
Limestone (includes aragonite, marble, chalk, coral)	113,000 r	1,810	114,000	2,230
Cement rock (includes marl)	12,700	2	11,300	2
Cement kiln dust (CKD)[4]	333	165	334	414
Lime[5]	24	29	9	30
Other	23	19	26	21
Aluminous:				
Clay	4,630 r	--	4,790	--
Shale	3,700	29	3,780	30
Other[6]	661	--	721	--
Ferrous, iron ore, pyrites, millscale, other	1,330 r	--	1,553	--
Siliceous:			--	--
Sand and calcium silicate	3,150	--	3,010	--
Sandstone, quartzite, soils, other	878	6	950	--
Fly ash	2,890	77	2,950	153
Other ash, including bottom ash	1,050	--	1,210	--
Granulated blast furnace slag[7]	104	345	144	521
Other blast furnace slag	189	--	255	--
Steel slag	401	--	525	--
Other slags	53	--	58	2
Natural rock pozzolans[8]	--	6	--	8
Other pozzolans[9]	114	19	222	62
Other:				
Gypsum and anhydrite	--	5,200 r	--	5,370
Other, n.e.c.[10]	106	98	84	108
Total[11]	146,000 r	7,810 r	146,000	8,940
Clinker, imported, raw materials equivalent[11]	--	4,400 r	--	4,750
Grand total[12]	146,000 r	12,200 r	146,000	13,700

rRevised. -- Zero.

[1]Nonfuel raw materials. Excludes Puerto Rico.

[2]Data have been rounded to three significant digits to reflect inherent reporting accuracy and the incorporation of estimates for some facilities.

[3]Includes portland, blended, and masonry cements.

[4]Data are underreported.

[5]Data are probably underreported, especially regarding incorporation within masonry cements.

[6]Includes alumina, aluminum dross, bauxite, catalysts, staurolite, and other materials.

[7]Includes both ground (GGBFS) and unground material.

[8]Includes pozzolana and burned clays and shales except where reported directly as clay or shale.

[9]Includes diatomite, silica fume, other microcrystalline silica, and other pozzolans, whether or not used as such

[10]Not elsewhere classified.

[11]Converted as the weight of foreign clinker consumed times 1.7.

[12]Data may not add to totals shown because of independent rounding.

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TABLE 7

CLINKER PRODUCED AND FUEL CONSUMED BY THE CEMENT INDUSTRY IN THE UNITED STATES, BY PROCESS[1]

Kiln process	Clinker produced[2]			Fuel consumed					Waste fuel	
	Active plants	Quantity (thousand metric tons)	Percentage of total	Coal[3] (thousand metric tons)	Petroleum coke (thousand metric tons)	Oil[4] (thousand liters)	Natural gas (thousand cubic meters)	Tires (thousand metric tons)	Solid (thousand metric tons)	Liquid (thousand liters)
2004:										
Wet	24	14,165	16.3	1,730	584	29,300	36,700	61	38	771,000
Dry	78 [5]	67,160 [5]	77.5 [5]	7,230 [5]	1,600	74,600 [5]	299,000	312	71	186,000 [5]
Both[6]	5	5,333	6.2	700	77	691	60,000	5	16	40,400
Total[7]	107 [5]	86,658 [5]	100.0 [5]	9,660 [5]	2,260	105,000 [5]	396,000	377	125	997,000 [5]
2005:										
Wet	23	11,807	13.5	1,480	586	29,300	22,800	85	9	479,000
Dry	79	70,809	81.0	7,340	1,740	58,000	310,000	315	110	894,000
Both[6]	4	4,790	5.5	679	21	--	62,000	5	10	93,300
Total[7]	106	87,405	100.0	9,490	2,350	87,300	395,000	405	130	1,470,000

-- Zero.

[1]All fuel data have been rounded to three significant digits.

[2]Clinker data were all reported; although unrounded, data are thought to be accurate to no more than three significant digits.

[3]All reported to be bituminous.

[4]Distillate and residual fuel oils; excludes used oils included under liquid wastes.

[5]Revised to exclude Puerto Rico.

[6]Fuel quantities may not represent normal operating conditions owing to the inclusion of plants that were converted from wet to dry technology during the year.

[7]Data may not add to totals shown because of independent rounding.

TABLE 8

ELECTRIC ENERGY USED AT CEMENT PLANTS IN THE UNITED STATES, BY PROCESS

Plant process	Electric energy used[1]						Finished cement produced[3] (thousand metric tons)	Average consumption (kilowatthours per metric ton of cement produced)
	Generated at plant		Purchased		Total			
	Number of plants	Quantity (million kilowatthours)	Number of plants	Quantity (million kilowatthours)	Quantity[2] (million kilowatthours)	Percentage		
2004:								
Integrated plants:								
Wet	--	--	24	2,170	2,170	16.1 [4]	15,770	137
Dry	4	456	78 [4]	10,000 [4]	10,500 [4]	77.8 [4]	73,465 [4]	142 [4]
Both[5]	--	--	5	822	822	6.1 [4]	5,642	146
Total or average[2]	4	456	107 [4]	13,000 [4]	13,500 [4]	100.0	94,877 [4]	142
Grinding plants[6]	--	--	6	198	198	--	2,392	83
Exclusions[7]	--	--	2	NA	NA	--	165	NA
2005:								
Integrated plants:								
Wet	--	--	23	1,770	1,770	13.1	13,075	135
Dry	5	486	79	10,400	10,900	80.7	78,423	139
Both[5]	--	--	4	770	770	5.7	5,029	153
Total or average[2]	5	486	106	13,000	13,500	100.0	96,527	139
Grinding plants[6]	--	--	7	214	214	--	2,562	84
Exclusions[7]	--	--	2	NA	NA	--	229	NA

NA Not available. -- Zero.

[1]Electricity data are rounded because they include estimates for a number of nonrespondent plants or incomplete reporting by respondent facilities.

[2]Data may not add to totals shown because of independent rounding.

[3]Includes portland and masonry cements. Data are all reported and have not been rounded.

[4]Revised to exclude Puerto Rico.

[5]Electricity consumption may not represent normal operating conditions owing to the inclusion of plants that were converted from wet to dry technology during the year.

[6]Excludes plants that reported production only of masonry cement.

[7]Tonnage of cement produced by plants that reported production of masonry cement only.

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TABLE 9

CEMENT SHIPMENTS TO FINAL CUSTOMER, BY DESTINATION AND ORIGIN[1, 2]

(Thousand metric tons)

Destination and origin	Portland cement		Masonry cement	
	2004	2005	2004	2005
Destination:				
Alabama	1,643	1,738	172	183
Alaska[3]	175	173	--	--
Arizona	4,117	4,671	113	102
Arkansas	1,173	1,205	83	97
California, northern	5,044	5,377	125	148
California, southern	9,177	9,945	537	540
Colorado	2,440	2,521	30	33
Connecticut[3]	828	799	19	19
Delaware[3]	181	208	13	13
District of Columbia[3]	191	205	(4)	(4)
Florida	9,698	11,233	879	1,052
Georgia	4,109	4,395	354	357
Hawaii	380	431	5	7
Idaho	685	704	1	1
Illinois, excluding Chicago	2,068	2,437	27	28
Illinois, metropolitan Chicago[3]	1,919	1,669	65	70
Indiana	2,238	2,182	97	92
Iowa	1,842	1,933	6	6
Kansas	1,535	1,537	14	11
Kentucky	1,395	1,486	114	117
Louisiana[3]	1,882	1,935	66	65
Maine	234	234	5	5
Maryland	1,542	1,568	91	92
Massachusetts[3]	1,322	1,242	24	22
Michigan	3,175	2,924	146	135
Minnesota[3]	2,077	2,016	47	39
Mississippi	974	1,067	67	69
Missouri	2,623	2,816	49	52
Montana	407	380	1	1
Nebraska	1,308	1,356	9	6
Nevada	2,382	2,602	29	27
New Hampshire[3]	221	229	5	5
New Jersey[3]	2,036	1,964	89	94
New Mexico	940	901	9	8
New York, eastern	663	653	23	19
New York, western[3]	879	817	30	27
New York, metropolitan[3]	1,694	1,681	87	92
North Carolina[3]	2,743	2,900	326	352
North Dakota[3]	402	359	2	2
Ohio	3,999	3,893	191	171
Oklahoma	1,442	1,603	62	71
Oregon	1,119	1,237	1	1
Pennsylvania, eastern	2,230	2,214	73	71
Pennsylvania, western	1,166	1,096	60	56
Rhode Island[3]	178	188	4	3
South Carolina	1,742	1,778	147	166
South Dakota	512	483	2	2
Tennessee	1,875	2,111	256	278
Texas, northern	6,222	6,793	148	164
Texas, southern	6,874	7,680	219	257
Utah	1,373	1,526	(4)	(4)

See footnotes at end of table.

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TABLE 9—Continued
CEMENT SHIPMENTS TO FINAL CUSTOMER, BY DESTINATION AND ORIGIN[1, 2]

(Thousand metric tons)

Destination and origin	Portland cement		Masonry cement	
	2004	2005	2004	2005
Destination—Continued:				
Vermont[3]	144	129	3	3
Virginia	2,478	2,666	189	203
Washington	2,090	2,238	2	2
West Virginia	488	512	29	27
Wisconsin	2,329	2,348	28	25
Wyoming	463	466	(4)	1
Total[5]	115,066	121,448	5,172	5,489
Foreign countries[6]	492	424	1	(4)
Puerto Rico	1,879	1,857	--	--
Grand total[5]	117,435	123,730	5,172	5,489
Origin:				
United States	93,323	94,004	5,115	5,429
Puerto Rico	1,585	1,584	--	--
Foreign countries[7]	22,527	28,142	57	60
Total shipments[5]	117,435	123,730	5,172	5,489

-- Zero.

[1]Includes cement produced from imported clinker and imported cement shipped by domestic producers and importers.

[2]Data are developed from consolidated monthly surveys of shipments by companies and may differ from data in tables 1, 10-12, and 14-15, which are from annual surveys of individual plants and importers. Includes any revisions to monthly data available through August 31, 2005. Although presented unrounded, data are thought to be accurate to no more than three significant digits.

[3]Has no cement plants.

[4]Less than ½ unit.

[5]Data may not add to totals shown because of independent rounding.

[6]Includes shipments to U.S. possessions and territories.

[7]Imported cement distributed in the United States as reported by domestic producers and other importers. Data do not match the imports calculated from tables 17 and 21.

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TABLE 10
SHIPMENTS OF PORTLAND CEMENT FROM MILLS IN THE UNITED STATES,
IN BULK AND IN CONTAINERS, BY TYPE OF CARRIER[1, 2]

(Thousand metric tons)

	Shipments from plant to terminal		Shipments to final domestic consumer				
			From plant to consumer		From terminal to consumer		Total shipments
	In bulk	In containers[3]	In bulk	In containers[3]	In bulk	In containers[3]	to consumer[4]
2004:							
Railroad	13,700	47	1,690	8	456 r	1	2,160 r
Truck	4,210 r	563	60,200 [5]	1,520 [5]	49,800 [5]	790 [5]	112,000 [5]
Barge and boat	9,100 r	10	99	--	--	--	99 r
Total[4]	27,000	620	62,000 [5]	1,530 [5]	50,300 [5]	791 [5]	115,000 [5, 6]
2005:							
Railroad	12,000	13	1,570	18	488	--	2,080
Truck	3,920	200	62,700	1,940	54,800	723	120,000
Barge and boat	8,970	--	80	--	--	--	80
Total[4]	24,900	214	64,400	1,960	55,200	723	122,000 [6]

rRevised. -- Zero.

[1]Includes imported cement and cement made from imported clinker.

[2]Data are rounded to no more than three significant digits because they include estimates.

[3]Includes packages, bags, and jumbo bags.

[4]Data may not add to totals shown because of independent rounding.

[5]Revised to exclude Puerto Rico.

[6]Shipments calculated on the basis of an annual survey of plants and importers; may differ from totals in table 9, which are based on consolidated monthly data.

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TABLE 11

PORTLAND CEMENT SHIPPED BY PRODUCERS AND IMPORTERS IN THE UNITED STATES, BY DISTRICT[1]

District[3,4]	2004 Quantity (thousand metric tons)	2004 Value[2] Total (thousands)	2004 Value[2] Average (dollars per metric ton)	2005 Quantity (thousand metric tons)	2005 Value[2] Total (thousands)	2005 Value[2] Average (dollars per metric ton)
Maine and New York	3,556	$269,944	75.91	3,434	$305,647	89.00
Pennsylvania, eastern	4,830 [5]	363,000 [5]	75.00 [5]	4,686	411,000 [5]	87.50 [5]
Pennsylvania, western	1,535	120,000 [5]	78.00 [5]	1,563	139,204	89.06
Illinois	3,052	235,921	77.31	3,280 [5]	291,000 [5]	88.50 [5]
Indiana	3,013	213,484	70.85	3,141	249,419	79.40
Michigan and Wisconsin	6,611	535,000 [5]	81.00 [5]	6,170 [5]	574,000 [5]	93.00 [5]
Ohio	1,005	81,000 [r,5]	80.50 [r,5]	984	89,069	90.48
Iowa, Nebraska, South Dakota	4,802	394,319	82.12	5,151	474,693	92.16
Kansas	2,222	175,000 [5]	79.00 [5]	2,376	200,526	84.41
Missouri	6,058	446,008	73.63	6,281	546,361	86.99
Florida	9,430 [5]	776,000 [5]	82.50 [5]	10,841	982,819	90.65
Georgia, Virginia, West Virginia	2,951	220,030	74.55	3,001	256,000 [5]	85.50 [5]
Maryland	2,733	189,628	69.38	2,842	234,227	82.41
South Carolina	3,491	220,162	63.06	3,827	289,278	75.59
Alabama	4,621	308,181	66.69	5,459	448,929	82.24
Kentucky, Mississippi, Tennessee	3,087	227,798	73.79	3,281	284,667	86.77
Arkansas and Oklahoma	2,658	198,487	74.68	2,998	250,345	83.51
Texas, northern	7,678	559,000 [5]	73.00 [5]	8,096	681,000 [5]	84.00 [5]
Texas, southern	6,270 [5]	435,000 [5]	69.50 [5]	6,674	534,932	80.15
Arizona and New Mexico	3,969	368,314	92.80	4,600 [5]	465,000 [5]	101.00 [5]
Colorado and Wyoming	2,786	206,658	74.19	2,704	237,000 [5]	87.50 [5]
Idaho, Montana, Nevada, Utah	3,245	268,775 [r]	82.82 [r]	3,473	323,457	93.13
Alaska and Hawaii	499	64,680	129.53	560	78,247	139.72
California, northern	4,257	369,806	86.88	4,518	443,260	98.11
California, southern	10,764	881,243	81.87	11,575	1,125,323	97.22
Oregon and Washington	2,690 [5]	207,000 [5]	77.00 [5]	3,040 [5]	268,000 [5]	88.00 [5]
Independent importers, n.e.c.[6,7]	6,790 [5]	598,000 [5]	88.00 [5]	7,740 [5]	745,000 [5]	96.50 [5]
Total or average[8]	115,000 [5,9]	8,930,000 [r,5]	78.00 [5]	122,000 [5,9]	10,900,000 [5]	89.00 [5]
Puerto Rico	1,868	W	W	1,867	W	W
Grand total[8]	116,000 [5,9]	W	W	124,000 [5,9]	W	W

[r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Includes portland cement (gray and white) and cement produced from imported clinker. Even where presented unrounded, data are thought to be accurate to no more than three significant digits.

[2]Values represent mill net or ex-plant (free on board plant) valuations of total sales to final customers, including sales from plant distribution terminals. The data are ex-terminal for independent terminals. All varieties of portland cement, and both bag and bulk shipments, are included. Unless otherwise specified, data are presented unrounded but may include cases where value data (only) were missing from survey forms and so were estimated. Accordingly, unrounded value data should be viewed as cement value indicators, good to no better than the nearest $0.50 or even $1.00 per metric ton.

[3]District is the location of the reporting facility, not the location of sales.

[4]Includes shipments by independent importers where regional assignations were possible.

[5]Data are rounded (unit values to the nearest $0.50) because they include estimated data.

[6]Importers for which district assignations were not possible.

[7]Not elsewhere classified.

[8]Data may not add to totals shown because of independent rounding.

[9]Shipments calculated on the basis of an annual survey of plants and importers; may differ from data in table 9, which are based on consolidated company monthly data.

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TABLE 12

MASONRY CEMENT SHIPPED BY PRODUCERS AND IMPORTERS IN THE UNITED STATES, BY DISTRICT[1, 2]

	2004			2005		
		Value[3]			Value[3]	
District[4]	Quantity (thousand metric tons)	Total (thousands)	Average (dollars per metric ton)	Quantity (thousand metric tons)	Total (thousands)	Average (dollars per metric ton)
Maine and New York	122	$12,100 [5]	99.50 [5]	118	$12,751	108.06
Pennsylvania	345	39,767 [5]	115.50 [5]	342 [5]	42,600 [5]	124.50 [5]
Illinois, Indiana, Ohio	532	62,500 [5]	117.50 [5]	536	68,340	127.50
Michigan	255	30,000 [5]	117.50 [5]	232 [5]	28,000 [5]	120.50 [5]
Iowa, Nebraska, South Dakota	35	4,627	132.92	40	3,728	93.20
Kansas and Missouri	154	18,166	118.23	169	21,279	125.91
Florida	775	99,200 [5]	128.00 [5]	945	134,930	142.78
Georgia, Maryland, Virginia, West Virginia	455	66,000 [5]	145.00 [5]	476	75,800 [5]	159.50 [5]
South Carolina	400	44,073	110.06	473	51,539	108.96
Alabama	425	48,875	114.98	500	57,727	115.45
Kentucky, Mississippi, Tennessee	125	15,000	119.73	127	16,364	128.85
Arkansas and Oklahoma	157	16,724	106.61	190	20,508	107.94
Texas, northern	163	22,800 [5]	139.50 [5]	188	26,200 [5]	139.00 [5]
Texas, southern	172	17,111	99.75	186	19,814	106.53
Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming	147	15,513	105.71	156	18,706	119.91
Alaska and Hawaii	4	914	209.44	5	1,234	246.80
California, northern; Oregon; Washington	84	9,710 [5]	115.00 [5]	71	9,060 [5]	127.50 [5]
California, southern	599	57,115	95.30	628	72,178	114.93
Independent importers, n.e.c.[6, 7]	43 [5]	4,910 [5]	114.00 [5]	24 [5]	3,480 [5]	145.00 [5]
Total or average[8]	4,990 [5, 9]	585,000 [5]	117.00 [5]	5,410 [5, 9]	684,000	126.50

[1]Shipments are to final customers and include imported cement and cement made from imported clinker. Data exclude Puerto Rico, which did not record any masonry cement sales. Even where presented unrounded, data are thought to be accurate to no more than three significant digits.

[2]Includes gray, white, and colored varieties of masonry, portland-lime, and plastic cements.

[3]Values represent ex-plant (free on board) valuations of total sales to final customers, including sales from distribution terminals. Even where presented unrounded, data should be viewed as cement value indicators, good to no better than the nearest $0.50 or even $1.00 per metric ton.

[4]District location is that of the reporting facilities, not necessarily the location of sales.

[5]Data are rounded (unit values to the nearest $0.50) because they include estimated data.

[6]Importers for which district assignations were not possible.

[7]Not elsewhere classified.

[8]Data may not add to totals shown because of independent rounding.

[9]Tonnages based on an annual survey of plants and terminals and may differ from the totals in table 9, which represent consolidated monthly surveys of companies.

TABLE 13

AVERAGE MILL NET VALUE OF CEMENT IN THE UNITED STATES[1, 2]

(Dollars per metric ton)

Year	Gray portland cement	White portland cement[3]	All portland cement	Prepared masonry cement	All classes of cement
2004	77.00 [r]	164.00	78.00	117.00	79.50
2005	88.50	176.00	89.00	126.50	91.00

[r]Revised.

[1]Excludes Puerto Rico. Values are the average of sales to final customers, free on board plant or import terminal, less all discounts, allowances, and onward delivery charges to customers or distribution terminals, but inclusive of bagging charges.

[2]Data are rounded to the nearest $0.50 because they include estimates.

[3]The unit values for white cement include a component of resales showing significant price markups.

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TABLE 14

PORTLAND CEMENT SHIPMENTS IN 2005, BY DISTRICT AND TYPE OF CUSTOMER[1]

(Thousand metric tons)

District[2, 3]	Ready-mixed concrete	Concrete product manufacturers[4]	Contractors[5]	Building material dealers	Oil well, mining, waste[6]	Government and miscellaneous[7]	Total[8, 9]
Maine and New York	2,710	355	67	254	--	49	3,434
Pennsylvania, eastern	2,880	1,300	145	265	--	98	4,686
Pennsylvania, western	1,100	265	159	1	18	18	1,563
Illinois	2,540	249	147	51	177	119	3,280
Indiana	2,420	457	162	75	11	17	3,141
Michigan and Wisconsin	4,840	744	175	179	44	186	6,170
Ohio	793	151	10	15	1	15	984
Iowa, Nebraska, South Dakota	3,620	605	562	99	95	172	5,151
Kansas	1,860	158	221	85	53	1	2,376
Missouri	5,150	376	621	96	5	38	6,281
Florida	8,010	2,000	176	626	1	27	10,841
Georgia, Virginia, West Virginia	2,140	634	162	38	11	13	3,001
Maryland	2,250	318	141	55	2	79	2,842
South Carolina	2,730	706	256	94	2	40	3,827
Alabama	4,150	686	241	163	16	201	5,459
Kentucky, Mississippi, Tennessee	2,530	514	168	30	17	20	3,281
Arkansas and Oklahoma	2,140	144	461	130	75	44	2,998
Texas, northern	5,160	566	1,120	150	673	428	8,096
Texas, southern	4,530	719	767	152	480	31	6,674
Arizona and New Mexico	3,430	596	259	130	161	144	4,600
Colorado and Wyoming	2,060	299	146	68	111	19	2,704
Idaho, Montana, Nevada, Utah	2,730	243	182	41	230	46	3,473
Alaska and Hawaii	460	66	23	--	6	4	560
California, northern	3,670	462	309	69	3	5	4,518
California, southern	8,150	2,710	266	388	64	2	11,575
Oregon and Washington	2,110	537	180	151	56	9	3,040
Independent importers, n.e.c.[10, 11]	6,190	910	248	223	27	144	7,740
Total[9]	90,300	16,800	7,380	3,630	2,340	1,970	122,000
Puerto Rico	1,100	191	52	525	--	--	1,867
Grand total[9]	91,400	17,000	7,430	4,160	2,340	1,970	124,000

-- Zero.

[1]Includes imported cement and cement ground from imported clinker. Except for district totals, data have been rounded to three significant digits but are likely to be accurate to only two significant digits. District totals are accurate to no more than three significant digits.

[2]District location is that of the reporting facilities and may include sales by them into other districts.

[3]Includes shipments by independent importers for which district assignations were possible.

[4]Grand total shipments to concrete product manufacturers include brick and block—6,320; precast and prestressed—3,790; pipe—2,030; and other or unspecified—4,810.

[5]Grand total shipments to contractors include airport—198; road paving—3,820; soil cement—1,410; and other or unspecified—2,000.

[6]Grand total shipments include oil well drilling—1,850; mining—273; and waste stabilization—121.

[7]Includes shipments for which customer types were not specified.

[8]District totals are not rounded except in accord with the data in table 11.

[9]Data may not add to totals shown because of independent rounding.

[10]Shipments by independent importers for which district assignations were not possible.

[11]Not elsewhere classified.

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TABLE 15

PORTLAND CEMENT SHIPPED FROM PLANTS IN THE UNITED STATES TO DOMESTIC CUSTOMERS, BY TYPE[1, 2]

(Thousand metric tons)

Type	2004	2005
General use and moderate heat (Types I and II) (gray)[3]	90,000 r	93,900
High early strength (Type III)	3,820	3,960
Sulfate resisting (Type V)[3]	15,800	18,100
Block	609	555
Oil well	1,310	1,440
White[4]	1,130	1,190
Blended:		
Portland, natural pozzolans	49	40
Portland, granulated blast furnace slag	978	1,880
Portland, fly ash	343	362
Other blended cement[5]	486	883
Total[6]	1,860	3,160
Expansive and regulated fast setting	62	6
Miscellaneous[7]	32	2
Grand total[6, 8]	115,000 r	122,000

rRevised.

[1]Includes imported cement.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Cements classified as Type II/V hybrids are now commonly reported as Type V.

[4]Mostly Types I and II, but may include Types III-V and block varieties.

[5]Includes blends with other pozzolans, such as cement kiln dust and silica fume.

[6]Data may not add to totals shown because of independent rounding.

[7]Includes low heat (Type IV), waterproof, and other portland cements.

[8]Data are based on an annual survey of plants and importers; may differ from data on table 9, which are based on monthly consolidated data from companies.

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TABLE 16

U.S. AND PUERTO RICO EXPORTS OF HYDRAULIC CEMENT AND CLINKER, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

	2004		2005	
	Quantity	Value[2]	Quantity	Value[2]
United States:				
Argentina	(3)	53	1	123
Australia	(3)	48	3	288
Azerbaijan	9	425	3	160
Bahamas	21	2,613	31	3,733
Brazil	(3)	41	1	124
Canada	639	48,034	650	52,313
Cayman Islands	1	198	1	162
China	6	645	4	461
Dominican Republic	2 [4]	188 [4]	4	216
Equatorial Guinea	2	71	--	--
France	(3)	117	1	102
Greece	1	179	2	202
Guatemala	(3)	102	1	164
Hong Kong	2	157	3	185
Indonesia	--	--	1	33
Israel	(3)	24	1	35
Jamaica	1	42	(3)	48
Japan	1	74	1	66
Korea, Republic of	1	87	2	140
Mexico	41	4,699	28	4,787
Netherlands	(3)	3	1	30
Netherlands Antilles	(3)	51	1	127
Panama	1	85	1	129
Peru	(3)	53	3	189
Saudi Arabia	(3)	24	9	907
Spain	(3)	8	1	26
Sweden	1	74	1	60
Taiwan	3	171	4	179
Trinidad and Tobago	1	165	1	129
Turks and Caicos Islands	(3)	44	(3)	33
United Arab Emirates	1	80	1	211
United Kingdom	(3)	6	1	32
Venezuela	5	275	1	127
Other	9 [4]	1,445 [4]	4	1,271
Total[5]	749	60,281	766	66,789
Puerto Rico:				
Bahamas, The	--	--	1	60
Dominican Republic	69	2,741	35	1,415
Turks and Caicos Islands	--	--	1	32
Other	(3)	19	(3)	6
Total[5]	70	2,760	37	1,513
Grand total[5]	818	63,041	803	68,302

-- Zero.

[1]Includes portland and masonry cements.

[2]Free alongside ship value. The value of exports at the U.S. seaport or border point of export is based on the transaction price, including inland freight, insurance, and other charges incurred in placing the merchandise alongside the carrier. The value excludes the cost of loading.

[3]Less than ½ unit.

[4]U.S. data may appear to be revised because Puerto Rico data are now shown separately.

[5]Data may not add to totals shown because of independent rounding.

Source: U.S. Census Bureau.

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TABLE 17
U.S. AND PUERTO RICO IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

	2004			2005		
		Value			Value	
	Quantity	Customs[2]	C.i.f.[3]	Quantity	Customs[2]	C.i.f.[3]
United States:						
Belgium	2 [4]	624 [4]	665 [4]	1	149	161
Brazil	442	18,206	22,359	467	25,153	29,837
Bulgaria	231	12,478	15,069	303	16,921	20,325
Canada	5,753	319,651	338,988	5,404	319,259	338,523
China[5]	2,119 [4]	72,644 [4]	114,209 [4]	4,726	202,089	319,988
Colombia	2,121 [4]	83,935 [4]	116,107 [4]	1,844	94,981	123,758
Croatia	25	4,668	5,671	34	6,659	8,103
Denmark	156 [4]	11,681 [4]	16,786 [4]	227	16,316	24,978
Dominican Republic	--	--	--	77	4,406	6,188
Egypt	339	17,147	26,166	569	33,419	48,355
France	79	15,163	17,710	74	16,509	19,508
Germany	14	2,029	3,779	3	926	1,918
Greece	2,011	65,398	105,253	2,786	104,910	172,406
Hong Kong	--	--	--	77	1,858	1,911
Indonesia	630	22,490	41,804	865	29,481	58,713
Japan	2	593	867	4	1,155	1,832
Korea, Republic of	1,729	48,014	80,415	2,526	87,370	144,854
Mexico	1,429 [4]	62,520 [4]	81,067 [4]	2,173	110,281	138,030
Netherlands	7	3,338	4,111	31	5,033	5,865
Norway	365	23,388	25,642	522	25,299	32,574
Peru	644	21,335	35,871	1,047	35,546	60,527
Philippines	301	8,360	13,293	312	9,728	18,220
Spain	408 [4]	19,477 [4]	28,380 [4]	236	16,497	22,895
Sweden	1,058	31,483	55,336	1,050	35,421	59,660
Taiwan	1,068	42,014	69,345	1,759	71,448	124,679
Thailand	2,808	90,620	148,475	2,893	117,719	193,668
Turkey	755 [4]	26,602 [4]	42,737 [4]	675	28,873	50,665
United Arab Emirates	2	126	204	5	468	698
United Kingdom	19	6,097	6,625	14	4,907	5,211
Venezuela	2,505	99,419	140,571	2,484	119,203	170,362
Other	4 [4]	596 [4]	650 [4]	76	5,213	6,063
Total[6]	27,026 [4]	1,130,098 [4]	1,558,154 [4]	33,261	1,547,198	2,210,475
Puerto Rico:						
Denmark	217	6,638	13,255	212	8,054	13,499
Korea, Republic of	--	--	--	146	5,130	9,410
Other	62	2,592	4,019	33	2,406	3,234
Total[6]	279	9,230	17,274	391	15,590	26,142
Grand total[6]	27,305	1,139,328	1,575,428	33,652	1,562,788	2,236,617

-- Zero.

[1]Includes portland, masonry, and other hydraulic cements.

[2]Customs value. The price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.

[3]Cost, insurance, and freight. The import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry.

[4]U.S. data may appear to be revised because Puerto Rico data are now shown separately.

[5]China may be underrepresented and it is believed that all or some imports from Japan should be assigned to China.

[6]Data may not add to totals shown because of independent rounding.

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TABLE 18
U.S. AND PUERTO RICO IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY[1]

(Thousand metric tons and thousand dollars)

Customs district and country	2004			2005		
		Value			Value	
	Quantity	Customs[2]	C.i.f.[3]	Quantity	Customs[2]	C.i.f.[3]
United States:						
Anchorage, AK:						
Canada	11	731	1,350	8	449	898
Korea, Republic of	111	3,280	5,281	134	4,643	8,859
Total[4]	122	4,011	6,631	143	5,092	9,757
Baltimore, MD:						
Belgium	(5)	7	11	--	--	--
China	(5)	5	5	12	1,225	2,606
Germany	(5)	6	7	(5)	9	9
Netherlands	1	215	232	(5)	36	39
Norway	--	--	--	89	3,458	3,458
Taiwan	--	--	--	25	822	1,758
Venezuela	--	--	--	7	294	484
Total[4]	1	233	256	134	5,844	8,354
Boston, MA:						
Netherlands	(5)	83	102	(5)	48	51
Venezuela	127	4,756	6,634	132	5,292	8,246
Total[4]	128	4,839	6,737	132	5,339	8,298
Buffalo, NY:						
Canada	796	46,241	48,993	817	48,849	52,421
Croatia	--	--	--	(5)	76	112
Germany	(5)	12	13	--	--	--
United Kingdom	12	2,696	2,797	6	1,398	1,447
Total[4]	807 r	48,950	51,802	823	50,323	53,980
Charleston, SC:						
Brazil	--	--	--	37	2,126	2,151
China	6	758	1,062	--	--	--
Colombia	293	11,619	15,866	299	16,435	20,142
Greece	451	16,273	27,461	686	25,491	45,975
Italy	--	--	--	(5)	362	1,146
Netherlands	(5)	18	22	(5)	48	54
Spain	46	391	1,048	23	1,428	1,450
Sweden	(5)	58	68	(5)	13	16
Switzerland	--	--	--	(5)	12	15
United Kingdom	2	1,105	1,126	2	883	967
Venezuela	7	683	1,132	55	3,023	3,993
Total[4]	805 r	30,905	47,785	1,102	49,820	75,909
Chicago, IL:						
Canada	34	1,833	1,936	--	--	--
Japan	(5)	72	83	(5)	74	85
Netherlands	1	580	726	1	729	866
Spain	--	--	--	(5)	2	3
United Kingdom	--	--	--	(5)	3	3
Total[4]	35 r	2,485	2,745	1	809	958
Cleveland, OH:						
Canada	699	35,946	37,412	791	42,374	44,236
Mexico	(5)	7	11	--	--	--
Netherlands	(5)	278	319	(5)	360	411
United Kingdom	(5)	65	88	--	--	--
Total[4]	699	36,295	37,830	792	42,734	44,647

See footnotes at end of table.

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TABLE 18—Continued
U.S. AND PUERTO RICO IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY[1]

(Thousand metric tons and thousand dollars)

	2004			2005		
		Value			Value	
Customs district and country	Quantity	Customs[2]	C.i.f.[3]	Quantity	Customs[2]	C.i.f.[3]
United States—Continued:						
Columbia-Snake, OR:						
Canada	128	6,720	7,224	111	5,277	5,787
China	506	16,053	22,564	672	23,704	39,359
Korea, Republic of	21	715	1,056	84	2,853	4,399
Total[4]	655 r	23,488	30,843	867	31,834	49,545
Detroit, MI:						
Brazil	127	5,454	5,504	53	2,298	2,318
Canada	1,320	82,765	85,106	1,263	79,344	81,192
Denmark	(5)	5	5	--	--	--
Germany	--	--	--	(5)	20	21
Netherlands	(5)	47	59	(5)	82	95
South Africa	--	--	--	(5)	8	9
United Kingdom	1	252	304	1	339	339
Total[4]	1,448	88,523	90,978	1,317	82,092	83,974
Duluth, MN, Canada	172	7,854	8,762	158	7,121	7,951
El Paso, TX, Mexico	368	17,004	20,703	724	30,161	37,437
Great Falls, MT:						
Canada	51	2,528	2,619	62	3,078	3,282
Japan	(5)	4	4	--	--	--
Total[4]	51	2,532	2,622	62	3,078	3,282
Honolulu, HI:						
China	55	1,757	3,257	39	1,221	2,362
Korea, Republic of	21	609	1,449	--	--	--
Philippines	301	8,360	13,293	312	9,728	18,220
Taiwan	--	--	--	77	2,541	4,524
Thailand	40	1,080	1,794	--	--	--
Total[4]	417	11,806	19,793	428	13,490	25,106
Houston-Galveston, TX:						
Chile	(5)	29	35	--	--	--
China	--	--	--	243	9,063	17,052
Colombia	119	7,511	7,944	116	8,371	9,462
Egypt	29	2,282	2,971	263	13,428	21,985
France	(5)	84	94	(5)	18	20
Germany	(5)	90	110	(5)	113	136
Greece	206	6,266	9,252	292	11,042	16,723
Korea, Republic of	1,138	31,751	49,999	1,259	45,315	70,928
Peru	31	1,141	1,576	47	1,013	1,603
Thailand	--	--	--	309	15,682	27,591
Turkey	69	2,158	3,360	44	2,024	3,265
United Arab Emirates	--	--	--	1	106	170
United Kingdom	(5)	158	190	1	249	249
Venezuela	375	16,464	22,446	44	2,462	3,552
Total[4]	1,969	67,934	97,977	2,619	108,886	172,737
Laredo, TX, Mexico	158	18,052	18,989	142	16,531	17,386
Los Angeles, CA:						
China	1,196	42,085	64,956	1,874	80,939	128,099
Colombia	2	176	257	1	165	290
Egypt	2	150	245	(5)	37	73
Indonesia	78	5,857	8,775	211	7,385	13,630
Japan	(5)	142	233	2	647	1,079

See footnotes at end of table.

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TABLE 18—Continued
U.S. AND PUERTO RICO IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY[1]

(Thousand metric tons and thousand dollars)

Customs district and country	2004			2005		
		Value			Value	
	Quantity	Customs[2]	C.i.f.[3]	Quantity	Customs[2]	C.i.f.[3]
United States—Continued:						
Los Angeles, CA—Continued:						
Malaysia	--	--	--	(5)	4	4
Netherlands	--	--	--	(5)	17	22
Peru	1	86	128	2	196	294
Taiwan	260	10,487	14,904	214	9,694	14,053
Thailand	974	36,655	62,244	745	34,031	55,466
United Arab Emirates	1	79	114	3	308	437
United Kingdom	1	172	172	(5)	189	189
Total[4]	2,513	95,889	152,028	3,053	133,613	213,635
Miami, FL:						
Belgium	2	596	630	1	132	140
Brazil	(5)	6	9	--	--	--
China	--	--	--	85	3,231	6,250
Colombia	30	1,800	2,798	16	1,782	2,472
Denmark	4	862	1,369	51	3,647	5,536
Egypt	14	546	847	33	1,225	2,149
Germany	(5)	25	29	(5)	120	132
Greece	485	14,784	21,498	439	16,157	26,207
Guyana	1	384	387	--	--	--
Italy	--	--	--	(5)	14	17
Mexico	--	--	--	86	8,564	10,781
Peru	(5)	10	15	--	--	--
Spain	346	18,593	26,575	96	7,743	12,769
Sweden	1,055	28,737	52,156	1,006	32,229	55,452
Taiwan	--	--	--	13	941	1,448
Thailand	--	--	--	80	2,996	5,959
Turkey	248	7,546	10,905	238	9,189	15,442
United Kingdom	(5)	125	158	(5)	74	74
Venezuela	109	5,473	7,786	120	6,783	9,389
Total[4]	2,294	79,488	125,161	2,265	94,826	154,218
Milwaukee, WI, Canada	278	14,090	14,365	198	8,836	8,936
Minneapolis, MN, Canada	--	--	--	38	2,086	2,302
Mobile, AL:						
China	--	--	--	15	653	1,077
Colombia	231	7,761	13,351	137	5,977	8,988
Egypt	--	--	--	16	769	1,295
Greece	--	--	--	14	689	1,152
Korea, Republic of	--	--	--	15	631	1,017
Peru	61	1,858	3,902	--	--	--
Taiwan	--	--	--	8	352	612
Thailand	97	2,288	3,763	61	2,711	4,786
Turkey	12	351	626	--	--	--
United Kingdom	(5)	45	62	--	--	--
Venezuela	128	5,512	7,602	248	12,760	16,706
Total[4]	528 r	17,815	29,307	514	24,542	35,632
New Orleans, LA:						
China	5	542	760	552	29,337	38,095
Colombia	213	6,865	9,068	180	6,937	9,141
Croatia	25	4,663	5,666	33	6,230	7,544
Egypt	268	13,102	20,069	153	13,371	14,892

See footnotes at end of table.

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TABLE 18—Continued
U.S. AND PUERTO RICO IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY[1]

(Thousand metric tons and thousand dollars)

Customs district and country	2004			2005		
		Value			Value	
	Quantity	Customs[2]	C.i.f.[3]	Quantity	Customs[2]	C.i.f.[3]
United States—Continued:						
New Orleans, LA—Continued:						
Greece	370	11,530	19,002	245	9,553	17,018
Korea, Republic of	437	11,659	22,630	897	29,316	52,462
Netherlands	(5)	58	72	--	--	--
Norway	29	2,875	5,129	--	--	--
Peru	550	18,240	30,249	998	34,336	58,631
Spain	--	--	--	78	5,652	6,533
Taiwan	--	--	--	528	16,179	40,089
Thailand	464	12,887	25,976	238	7,511	15,827
Turkey	137	7,526	13,006	102	6,647	11,095
United Kingdom	(5)	6	7	(5)	177	177
Venezuela	52	2,303	3,387	90	5,658	7,162
Total[4]	2,551	92,255	155,023	4,095	170,906	278,666
New York, NY:						
China	--	--	--	8	281	611
Colombia	1	90	155	1	125	176
Croatia	(5)	5	5	--	--	--
France	--	--	--	(5)	5	5
Germany	11	1,040	1,232	--	--	--
Greece	255	7,910	14,699	403	14,728	25,929
Netherlands	(5)	102	123	26	2,194	2,443
Norway	336	20,513	20,513	432	21,841	29,116
Poland	(5)	85	90	(5)	59	62
Sweden	3	2,273	2,652	7	1,812	2,164
Taiwan	--	--	--	37	1,194	2,490
Thailand	10	230	250	--	--	--
Turkey	31	1,054	2,018	159	6,023	11,573
United Kingdom	2	952	1,055	1	719	723
Venezuela	190	7,317	10,642	190	10,891	14,172
Total[4]	839	41,571	53,435	1,265	59,872	89,464
Nogales, AZ, Mexico	546 r	25,276	39,130	1,068	46,007	63,252
Norfolk, VA:						
Bulgaria	231	12,478	15,069	303	16,921	20,325
Canada	10	322	538	--	--	--
China	--	--	--	36	1,306	2,753
Colombia	163	5,549	7,948	156	7,509	10,618
France	79	15,080	17,616	74	16,486	19,483
Germany	(5)	32	37	(5)	91	101
Greece	--	--	--	33	1,205	2,263
Netherlands	(5)	166	212	(5)	170	205
Sweden	1	415	460	11	511	578
United Kingdom	(5)	191	216	1	346	421
Venezuela	26	915	1,370	84	3,447	6,277
Total[4]	511	35,149	43,467	697	47,992	63,025
Ogdensburg, NY:						
Canada	384	26,212	26,654	336	24,042	24,402
Germany	(5)	4	4	(5)	5	5
United Kingdom	(5)	2	2	--	--	--
Total[4]	384	26,219	26,661	336	24,047	24,407
Pembina, ND, Canada	181	8,799	9,570	178	8,686	9,081

See footnotes at end of table.

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TABLE 18—Continued
U.S. AND PUERTO RICO IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY[1]

(Thousand metric tons and thousand dollars)

Customs district and country	2004			2005		
		Value			Value	
	Quantity	Customs[2]	C.i.f.[3]	Quantity	Customs[2]	C.i.f.[3]
United States—Continued:						
Philadelphia, PA:						
Belgium	(5)	21	24	(5)	18	21
China	(5)	13	17	--	--	--
Germany	3	694	2,195	2	401	1,270
Netherlands	3	1,355	1,719	2	993	1,257
Switzerland	--	--	--	74	4,598	4,618
Thailand	404	9,673	10,826	417	11,535	13,941
Total[4]	410	11,755	14,780	494	17,545	21,106
Portland, ME:						
Canada	98	9,624	9,653	156	18,254	19,168
Venezuela	31	1,667	1,677	--	--	--
Total[4]	128 r	11,291	11,330	156	18,254	19,168
Providence, RI:						
China	--	--	--	103	3,787	6,536
Turkey	--	--	--	82	3,120	5,908
Venezuela	648	22,773	33,043	555	22,125	34,829
Total[4]	648	22,773	33,043	740	29,031	47,274
San Diego, CA:						
Mexico	58	2,181	2,234	153	9,019	9,175
Taiwan	545	22,464	31,726	549	27,211	38,988
Thailand	76	2,955	3,932	15	1,468	1,999
Total[4]	678 r	27,600	37,892	717	37,698	50,162
San Francisco, CA:						
China	351	11,424	21,572	671	31,530	47,192
Denmark	(5)	13	14	--	--	--
Indonesia	553	16,634	33,029	654	22,096	45,082
Israel	--	--	--	(5)	8	8
Japan	--	--	--	(5)	3	3
Taiwan	263	9,063	22,716	200	8,128	13,149
Thailand	561	19,696	31,386	837	33,716	53,981
United Arab Emirates	1	47	89	1	55	91
United Kingdom	(5)	78	92	(5)	87	87
Total[4]	1,728 r	56,955	108,898	2,363	95,623	159,593
Savannah, GA:						
Colombia	3	263	385	79	4,309	5,420
Germany	(5)	127	152	--	--	--
Netherlands	(5)	143	168	(5)	25	26
Romania	(5)	3	3	--	--	--
United Kingdom	1	248	357	1	392	460
Total[4]	4	783	1,065	81	4,726	5,907
Seattle, WA:						
Canada	1,469	64,454	73,179	1,153	56,704	63,696
China	--	--	--	119	4,626	7,069
Germany	--	--	--	(5)	167	242
Japan	1	374	548	1	431	665
Korea, Republic of	--	--	--	136	4,612	7,189
Netherlands	(5)	11	12	(5)	14	17
Taiwan	--	--	--	51	2,097	3,236
Thailand	184	5,157	8,304	28	808	1,386
Total[4]	1,654	69,996	82,043	1,489	69,459	83,502

See footnotes at end of table.

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TABLE 18—Continued
U.S. AND PUERTO RICO IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY[1]

(Thousand metric tons and thousand dollars)

Customs district and country	2004			2005		
		Value			Value	
	Quantity	Customs[2]	C.i.f.[3]	Quantity	Customs[2]	C.i.f.[3]
United States—Continued:						
St. Albans, VT, Canada	123	11,532	11,628	134	14,160	15,172
St. Louis, MO:						
China	(5)	6	10	(5)	9	17
Croatia	--	--	--	1	353	447
Netherlands	(5)	284	344	(5)	318	379
Total[4]	1	290	353	1	681	842
Tampa, FL:						
Australia	--	--	--	(5)	37	37
Brazil	315	12,745	16,846	377	20,729	25,368
China	(5)	2	6	297	11,178	20,911
Colombia	932	37,284	51,443	586	29,828	39,721
Denmark	152	10,801	15,398	177	12,669	19,442
Egypt	27	1,066	2,034	103	4,589	7,961
Greece	244	8,635	13,340	675	26,044	37,140
Hong Kong	--	--	--	77	1,858	1,911
Spain	16	493	756	39	1,672	2,139
Sweden	--	--	--	25	856	1,451
Taiwan	--	--	--	57	2,288	4,332
Thailand	--	--	--	163	7,260	12,732
Turkey	258	7,967	12,821	50	1,869	3,382
United Kingdom	--	--	--	(5)	49	73
Venezuela	652	25,004	35,194	852	41,566	58,773
Total[4]	2,595	103,997	147,839	3,478	162,493	235,374
U.S. Virgin Islands:						
Bangladesh	2	95	134	--	--	--
Barbados	--	--	--	2	111	147
Venezuela	79	3,063	4,274	63	2,684	3,721
Total[4]	81	3,158	4,408	65	2,795	3,868
Wilmington, NC:						
Colombia	134	5,017	6,891	270	13,543	17,328
United Arab Emirates	--	--	--	77	4,406	6,188
Venezuela	83	3,490	5,384	42	2,217	3,057
Total[4]	217	8,506	12,275	390	20,166	26,573
U.S. total[4]	27,026 [6]	1,130,098 [6]	1,558,154 [6]	33,261	1,547,198	2,210,475
Puerto Rico, San Juan, PR:						
Argentina	--	--	--	(5)	4	4
Belgium	3	226	456	1	39	95
China	25	523	1,231	--	--	--
Colombia	3	238	319	5	589	806
Costa Rica	(5)	38	41	(5)	3	4
Denmark	217	6,638	13,255	212	8,054	13,499
Dominican Republic	(5)	11	11	--	--	--
Honduras	--	--	--	15	578	588
Korea, Republic of	--	--	--	146	5,130	9,410
Mexico	10	1,032	1,412	12	1,189	1,733
Panama	(5)	15	17	--	--	--
Spain	4	222	226	(5)	4	4
Turkey	16	288	308	--	--	--
Total[4]	279	9,230	17,274	391	15,590	26,142
Grand total[4]	27,305	1,139,328	1,575,428	33,652	1,562,788	2,236,617

See footnotes at end of table.

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TABLE 18—Continued
U.S. AND PUERTO RICO IMPORTS FOR CONSUMPTION OF HYDRAULIC CEMENT AND CLINKER, BY CUSTOMS DISTRICT AND COUNTRY[1]

[r]Revised. -- Zero.

[1]Includes all varieties of hydraulic cement and clicker.

[2]Customs value. The price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.

[3]Cost, insurance, and freight. The import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry.

[4]Data may not add to totals shown because of independent rounding.

[5]Less than ½ unit.

[6]U.S. data may appear to be revised because Puerto Rico data are now shown separately.

Source: U.S. Census Bureau.

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TABLE 19
U.S. AND PUERTO RICO IMPORTS FOR CONSUMPTION OF GRAY PORTLAND CEMENT, BY COUNTRY

(Thousand metric tons and thousand dollars)

Country	2004			2005		
		Value			Value	
	Quantity	Customs[1]	C.i.f.[2]	Quantity	Customs[1]	C.i.f.[2]
United States:						
Brazil	315	12,745	16,846	377	20,729	25,368
Bulgaria	231	12,478	15,069	303	16,921	20,325
Canada	4,744	247,821	264,773	4,301	242,961	260,188
China[3]	2,052 [4]	69,477 [4]	109,802 [4]	4,149	169,832	277,318
Colombia	1,874	71,964	100,591	1,599	78,333	103,969
Denmark	14 [4]	577 [4]	934 [4]	--	--	--
Egypt	291	13,359	20,841	350	15,843	27,309
Greece	2,007	64,313	104,168	2,755	103,952	171,448
Indonesia	630	22,490	41,804	865	29,481	58,713
Korea	1,729	48,014	80,415	2,443	84,944	141,159
Mexico	1,193	35,662	52,577	1,856	75,290	99,365
Norway	304	17,006	17,006	504	23,645	30,562
Peru	543	19,040	31,578	671	25,497	42,607
Philippines	301 [4]	8,360 [4]	13,293 [4]	312	9,728	18,220
Spain	253 [4]	6,614 [4]	10,223 [4]	52	1,882	3,033
Sweden	1,055	28,737	52,156	1,031	33,085	56,902
Taiwan	1,068	42,014	69,345	1,759	71,448	124,679
Thailand	2,726	86,160	140,787	2,864	113,556	188,138
Turkey	671 [4]	21,061 [4]	33,327 [4]	581	22,759	40,446
Venezuela	1,953	74,662	106,281	1,682	76,026	113,914
Other	13	1,185	1,390	98	3,533	3,663
Total[5]	23,968 [4]	903,741 [4]	1,283,206 [4]	28,551	1,219,444	1,807,328
Puerto Rico:						
China	25	523	1,231	--	--	--
Denmark	204	5,140	11,605	202	7,192	11,822
Korea	--	--	--	78	3,240	5,824
Spain	4	222	226	(6)	4	4
Turkey	16	288	308	--	--	--
Other	(6)	26	29	(6)	6	8
Total[5]	250	6,198	13,398	280	10,442	17,658
Grand total[5]	24,218	909,939	1,296,604	28,832	1,229,886	1,824,986

-- Zero.

[1]The price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.

[2]Cost, insurance, and freight. The import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry.

[3]China may be underrepresented and it is thought that all or some imports from Japan should be assigned to China.

[4]U.S. data may appear to be revised because Puerto Rico data are now shown separately.

[5]Data may not add to totals shown because of independent rounding.

[6]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 20
U.S. AND PUERTO RICO IMPORTS FOR CONSUMPTION OF WHITE CEMENT, BY COUNTRY

(Thousand metric tons and thousand dollars)

Country	2004			2005		
		Value			Value	
	Quantity	Customs[1]	C.i.f.[2,3]	Quantity	Customs[1]	C.i.f.[2,3]
United States:						
Australia	--	--	--	(4)	37	37
Belgium	2 [5]	603 [5]	641 [5]	1	132	140
Brazil	(4)	6	9	37	2,126	2,151
Canada	308	35,247	36,802	329	39,057	40,454
Chile	(4)	29	35	--	--	--
China	--	--	--	17	1,672	3,408
Colombia	27 [5]	2,735 [5]	3,533 [5]	42	4,112	5,507
Denmark	142 [5]	11,091 [5]	15,839 [5]	227	16,316	24,978
Dominican Republic	--	--	--	77	4,406	6,188
Egypt	48	3,788	5,325	24	2,200	2,780
Germany	(4)	23	27	(4)	34	36
Greece	3	1,085	1,085	31	958	958
Israel	--	--	--	(4)	8	8
Japan	--	--	--	(4)	10	10
Malaysia	--	--	--	(4)	4	4
Mexico	186 [5]	22,417 [5]	23,569 [5]	251	29,302	32,353
Netherlands	1	173	181	7	592	815
Norway	61	6,382	8,636	17	1,653	2,012
Peru	1	96	143	2	196	294
Spain	155	12,863	18,157	73	6,903	11,231
Switzerland	--	--	--	74	4,598	4,618
Thailand	23	2,939	4,354	29	4,163	5,530
Turkey	84	5,532	9,401	94	6,114	10,219
United Arab Emirates	2	126	204	5	468	698
Venezuela	125	5,774	8,914	121	7,007	9,628
Total[6]	1,168 [5]	110,910 [5]	136,855 [5]	1,457	132,067	164,055
Puerto Rico:						
Belgium	3	226	456	1	39	95
Colombia	3	238	319	5	589	806
Denmark	13	1,498	1,650	10	862	1,677
Mexico	10	1,032	1,412	12	1,189	1,733
Total[6]	29	2,994	3,836	28	2,680	4,311
Grand total[6]	1,197	113,904	140,691	1,485	134,747	168,366

-- Zero.

[1]Customs value. The price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.

[2]Cost, insurance, and freight. The import value represents the customs value plus insurance, freight and other delivery charges to the first port of entry.

[3]Values of less than $90.00 (c.i.f.) per metric ton likely indicate the mistaken total or partial inclusion of data for gray portland or similar cement or clinker. This error happens when the importer records the wrong tariff number with the U.S. Customs Service. Values that exceed $200 per ton likely indicate misidentified specialty cement, not white cement.

[4]Less than ½ unit.

[5]U.S. data may appear to be revised because Puerto Rico data are now shown separately.

[6]Data may not add to totals shown because of independent rounding.

Source: U.S. Census Bureau.

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TABLE 21

U.S. AND PUERTO RICO IMPORTS FOR CONSUMPTION OF CLINKER, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

	2004			2005		
		Value			Value	
Country	Quantity	Customs[2]	C.i.f.[3]	Quantity	Customs[2]	C.i.f.[3]
United States:						
Brazil	127	5,454	5,504	53	2,298	2,318
Canada	639	30,869	31,283	740	33,792	34,176
China	11	1,244	1,751	557	29,966	38,458
Colombia	220	9,237	11,982	203	12,536	14,282
Croatia	--	--	--	(4)	64	94
Egypt	--	--	--	184	12,379	14,627
France	77	13,614	15,953	72	15,250	18,106
Korea, Republic of	--	--	--	83	2,427	3,695
Peru	100	2,199	4,150	374	9,853	17,626
Spain	--	--	--	33	2,061	2,098
Sweden	--	--	--	15	542	599
Thailand	59	1,521	3,334	--	--	--
Venezuela	398	17,419	22,962	543	27,360	36,078
Total[5]	1,630 r	81,557	96,919	2,858	148,528	182,158
Puerto Rico:						
Honduras	--	--	--	15	578	588
Korea, Republic of	--	--	--	69	1,891	3,586
Total[5]	--	--	--	83	2,469	4,174
Grand total[5]	1,630 r	81,557	96,919	2,941	150,996	186,332

rRevised. -- Zero.

[1]For all types of hydraulic cement.

[2]Customs value. The price actually paid or payable for merchandise when sold for exportation to the United States, excluding U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise to the United States.

[3]Cost, insurance, and freight. The import value represents the customs value plus insurance, freight, and other delivery charges to the first port of entry.

[4]Less than ½ unit.

[5]Data may not add to totals shown because of independent rounding.

Source: U.S. Census Bureau.

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TABLE 22
HYDRAULIC CEMENT: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country	2001	2002	2003	2004	2005[e]
Afghanistan[e]	50	60	70	70	60
Albania	--	--	578	573	575 [3]
Algeria[e]	8,300	9,000	9,000	9,000	9,000
Angola	550 [r]	597 [r]	700 [r]	754 [r]	760
Argentina	5,545	3,911 [r]	5,217 [r]	6,254	7,595 [3]
Armenia	300	355	384	501 [r]	605 [3]
Australia[e]	7,500	7,550	8,000	8,000	9,000
Austria	3,802 [r]	3,918 [r]	3,886 [r]	3,976 [r]	4,736 [3]
Azerbaijan	523 [r]	848	1,013	1,428 [r]	1,538 [3]
Bahrain	89	67	129 [r]	153 [r]	191 [3]
Bangladesh[e]	5,005 [3, 4]	5,000	5,000	5,000	5,100
Barbados	250	298	325 [r]	322 [r]	320
Belarus	1,803	2,171	2,472	2,731 [r]	3,131 [3]
Belgium	7,157 [r]	6,980 [r]	6,550 [r]	6,715 [r]	7,000
Benin[e]	250	250	250	250	250
Bhutan[e]	160	160	160	170	170
Bolivia	983	1,010	1,138	1,276	1,440 [3]
Bosnia and Herzegovina	704	913	891	1,045	1,000
Brazil	38,927	38,027	34,010	34,413 [r]	36,673 [3]
Brunei	227	241	236 [r]	242 [r]	240
Bulgaria[e]	2,088 [3]	2,137 [3]	2,100	2,100	2,100
Burkina Faso[e]	50	30	30	30	30
Burma[5]	378	471 [r]	572	519 [r]	543 [3]
Cameroon	980 [r]	937 [r]	949 [r]	1,032 [r]	1,000
Canada	12,793 [r]	13,079 [r]	13,416 [r]	13,863 [r]	14,179 [3]
Chile	3,513	3,462	3,622	3,798	3,999 [3]
China	661,040	725,000	862,080	970,000 [r]	1,038,300 [p]
Colombia	6,830	6,064 [r]	7,337 [r]	7,822 [r]	9,959 [3]
Congo (Kinshasa)	201	265	331	403 [r]	410
Costa Rica[e]	1,200	1,200	1,600 [r]	1,900 [r]	2,000
Côte d'Ivoire[e]	650	650	650	650	650
Croatia	3,246	3,378	3,654	3,811	3,520 [3]
Cuba	1,324	1,327	1,346 [r]	1,366 [r]	1,370
Cyprus	1,369	1,438	1,637	1,689	1,805 [3]
Czech Republic	3,550	3,217	3,465	3,829 [r]	3,978 [3]
Denmark	2,047	2,028 [r]	1,953 [r]	2,150 [r]	2,200
Dominican Republic	2,746	3,050	2,783 [r]	2,636	2,640
Ecuador[e]	2,920 [3]	3,000	3,100	3,100	3,100
Egypt	25,700	28,155	26,639	28,763 [r]	29,000
El Salvador	1,174	1,318	1,390	1,256 [r]	1,400
Eritrea[e]	45	45	45	45	45
Estonia	405	466	506	615	650
Ethiopia[6]	900	900	1,130 [r]	1,316 [r]	1,568 [3]
Fiji[e]	95	95	100	100	100
Finland	1,325	1,198	1,493 [r]	1,691 [r]	1,321 [3]
France	19,839	19,437 [r]	19,655 [r]	20,962 [r]	21,277 [3]
French Guiana[e]	58 [3]	62 [3]	60 [r]	60 [r]	60
Gabon[e]	240 [r, 3]	257 [r, 3]	260 [r]	260 [r]	260
Georgia	335	347	345 [r]	425 [r]	450
Germany	32,118	31,009	32,749 [r]	31,854 [r]	30,629 [3]
Ghana[e]	1,900	1,900	1,900	1,900 [r]	1,900
Greece	14,819 [r]	14,282 [r]	14,638 [r]	15,039 [r]	15,000
Guadeloupe	265	230	230	230	230
Guatemala[e]	2,000	1,800	1,800 [r]	1,800 [r]	1,800

See footnotes at end of table.

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TABLE 22—Continued

HYDRAULIC CEMENT: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country	2001	2002	2003	2004	2005[e]
Guinea[e]	315 [3]	360	360	360	360
Haiti[e]	204 [3]	290 [3]	300	300	300
Honduras[e]	1,321 [3]	1,360	1,400	1,800 [r]	2,000
Hong Kong	1,279	1,206	1,189 [r]	1,039 [r]	1,005 [3]
Hungary	3,452	3,510	3,573	3,349 [r]	3,500
Iceland	125	83 [r]	90 [r]	90 [r, e]	95
India[e]	105,000	115,000	123,000 [3]	130,000 [r]	145,000
Indonesia	31,300	34,640	35,500 [r]	36,000 [e]	37,000
Iran	26,640	28,600	30,460 [r]	32,198 [r]	32,650 [3]
Iraq[e]	6,000	6,834 [3]	1,901 [r, 3]	2,500 [r]	3,000
Ireland	3,450 [r]	3,320 [r]	3,830 [r]	4,000 [r]	4,000
Israel	4,700 [e]	4,584	4,632	4,494	4,700
Italy	39,804	41,416 [r]	43,433 [r]	46,045 [r]	46,404 [3]
Jamaica	596	614	608	808 [r]	845 [3]
Japan	76,550	71,828	68,766	67,376 [r]	69,629 [3]
Jordan	3,173	3,558	3,515	3,908	4,046 [3]
Kazakhstan	2,029	2,129	2,570	3,662 [r]	3,975 [3]
Kenya	1,319	1,463	1,658	1,789	2,123 [3]
Korea, North[e]	5,160	5,320	5,540	5,630 [r]	5,700
Korea, Republic of	52,046	55,514	59,194	54,330 [r]	51,391 [3]
Kuwait	921	1,584	1,863 [r]	2,635 [r]	2,700
Kyrgyzstan	469	533	757	800 [e]	900
Laos[e]	92	240	250	250	350
Latvia	W	260	295	284	280
Lebanon	2,890	2,852	3,000 [r, e]	3,100 [r, e]	3,300
Liberia	63	54	25 [r]	40 [r]	40
Libya[e]	3,000	3,300	3,500 [3]	3,600	3,600
Lithuania	529	606	597	753	832 [3]
Luxembourg	729 [r]	728 [r]	714 [r]	797 [r]	750
Macedonia	630	600 [e]	768	820	800
Madagascar[e]	52 [3]	35 [r]	80 [r]	130 [r]	180
Malawi	181	174	24 [r]	120 [r]	120
Malaysia	13,820	14,336	17,243	15,690 [r]	17,860 [3]
Martinique[e]	255 [3]	221 [3]	220 [r]	220 [r]	220
Mauritania[e]	200	200	200	300 [r, 3]	300
Mexico	32,110	33,372	33,593	34,992	36,000
Moldova	200	300	255 [r]	440 [r]	500
Mongolia	68	148	162	62 [r]	112 [3]
Morocco[e]	10,000	10,200	10,400	11,000 [r]	11,000
Mozambique	265	285	362	370 [r, e]	400
Nepal[e, 4]	285	290	295	285	290
Netherlands	3,380 [r]	3,085 [r]	2,450 [r]	2,380 [r]	2,400
New Caledonia	93	100	100 [e]	100 [e]	100
New Zealand[e]	1,080 [3]	1,090	1,100	1,110 [3]	1,100
Nicaragua	514	549	590	600 [r, e]	610
Niger[e]	47 [r]	54 [r]	55 [r]	55 [r]	55
Nigeria[e]	2,400	2,100	2,300	2,300	2,400
Norway	1,642 [r]	1,631 [r]	1,650 [r]	1,420 [r]	1,500
Oman[e]	1,370 [3]	1,700	2,100	2,500	2,500
Pakistan[e]	11,000	11,000	13,000	16,000	18,000
Panama[e]	820	770	800 [r]	820 [r]	840
Paraguay[e]	650 [3]	650	660	650 [r]	650
Peru	3,950	3,980	4,000	4,590	4,600
Philippines	8,653	12,614	13,060 [r]	13,050 [r]	13,000

See footnotes at end of table.

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TABLE 22—Continued

HYDRAULIC CEMENT: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country	2001	2002	2003	2004	2005[e]
Poland	11,918	10,948	11,653	12,566 [r]	12,646 [3]
Portugal	10,162 [r]	9,759 [r]	8,567 [r]	8,843 [r]	9,000
Qatar[e]	1,240	1,340	1,400	1,400	1,400
Réunion[e]	380	380	380	380	380
Romania	5,668	5,680	5,992	6,239 [r]	7,032 [3]
Russia	35,300	37,700	41,000	45,700 [r]	48,700 [3]
Rwanda	91	101	105	104	105
Saudi Arabia[e]	20,608 [3]	22,000	23,000	25,400 [r]	26,064 [3]
Senegal	1,539	1,653 [r]	1,694 [r]	1,700 [r, e]	1,700
Serbia and Montenegro	2,418	2,396	2,075	2,240	2,200
Sierra Leone	113	144	169 [r]	180 [r]	180
Singapore[e]	600	200	150 [3]	-- [r]	--
Slovakia	3,123	3,141	3,147	3,158	3,499 [3]
Slovenia	1,237 [r]	1,178 [r]	1,370 [r]	1,186 [r]	1,200
South Africa, sales[7]	8,036	8,525	8,883 [r]	12,348	13,000
Spain, including Canary Islands	40,512	42,417	44,747 [r]	46,593 [r]	50,347 [3]
Sri Lanka	1,108	1,018	1,164	1,150 [r, e]	1,180
Sudan	190	205	272	307 [r]	310
Suriname[e]	65 [3]	65	65	65	65
Sweden	2,645 [r]	2,642 [r]	2,476 [r]	2,588 [r]	2,600
Switzerland	3,950 [r]	3,771	3,613 [r]	3,851 [r]	4,022 [3]
Syria	5,005 [r]	4,679 [r]	4,824 [r]	4,757 [r]	4,800
Taiwan	18,128	19,363	18,474	19,050	19,891 [3]
Tajikistan	70	100	166 [r]	194 [r]	253 [3]
Tanzania	900	1,026	1,186	1,281 [r]	1,375 [3]
Thailand	27,913	31,679	32,530	35,626	37,872 [3]
Togo[e]	800	800	800	800	800
Trinidad and Tobago	697	744	766	768 [r]	770
Tunisia	5,721	6,022	6,038	6,358	6,500
Turkmenistan[e]	450	450	450	450	450
Turkey	30,125	32,577	35,077	38,796 [r]	42,787 [3]
Uganda	431	506	507	559 [r]	650
Ukraine	5,800	7,142	8,900	10,600	12,183 [3]
United Arab Emirates[e]	6,100	7,000	8,000	8,000	8,000
United Kingdom	11,854	11,265 [r]	11,650 [r]	11,730 [r]	11,470 [3]
United States, including Puerto Rico[8]	90,450 [9]	91,266	94,329	99,015	100,903 [3]
Uruguay[e]	1,015 [3]	1,000	1,050	1,050	1,050
Uzbekistan[e]	4,000	4,000	4,000	4,800 [r]	5,068 [3]
Venezuela[e]	8,700	7,000	7,700	9,000	10,000
Vietnam	16,073	21,121	24,127 [r]	25,320	29,000 [3]
Yemen	1,493 [r]	1,561 [r]	1,541 [r]	1,546	1,550
Zambia[e]	215 [3]	230 [3]	350 [r]	480 [e]	435
Zimbabwe[e]	800	600	400	400	400
Total	1,740,000 [r]	1,850,000	2,030,000 [r]	2,190,000 [r]	2,310,000

See footnotes at end of table.

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TABLE 22—Continued

HYDRAULIC CEMENT: WORLD PRODUCTION, BY COUNTRY[1, 2]

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown. Even where presented unrounded, reported data are believed to be accurate to no more than three significant digits.

[2]Table includes data available through October 6, 2006. Data may include clinker exports for some countries.

[3]Reported figure.

[4]Data for year ending June 30 of that stated.

[5]Data are for fiscal year ending March 31 of the following year.

[6]July 7 of the year listed.

[7]Data are revised to remove sales of cementitious materials other than finished cement. Material sales removed (mostly fly ash and ground granulated blast furnace slag) amounted to: 2001—1,129; 2002—1,099; 2003—1,190; 2004—1,436; and 2005—1,440 (estimated).

[8]Portland and masonry cements only.

[9]Tonnage has been rounded to four significant digits.

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CHROMIUM

By John F. Papp

Domestic survey data and tables were prepared by Joseph M. Krisanda, statistical assistant, and the world production tables were prepared by Glenn J. Wallace, international data coordinator.

In 2005, the U.S. chromium supply (measured in contained chromium) was 124,000 metric tons (t) from recycled stainless steel scrap, 353,000 t from imports, and 474,000 t from Government and industry stocks. Supply distribution was 57,200 t to exports, 384,000 t to Government and industry stocks, and 511,000 t to apparent consumption. Chromium apparent consumption decreased by 8.02% compared with that of 2004.

Chromium has a wide range of uses in chemicals, metals, and refractory materials. Its use in iron, nonferrous alloys, and steel is for the purpose of enhancing hardenability or resistance to corrosion and oxidation. Production of stainless steel and nonferrous alloys are two of its more critical applications. Other applications are in alloy steel, catalysts, leather processing, pigments, plating of metals, refractories, and surface treatments.

Chromium is an essential trace element for human health. Some chromium compounds, however, are acutely toxic, chronically toxic, and/or carcinogenic. The U.S. Environmental Protection Agency (EPA) regulates chromium releases into the environment. The Occupational Safety and Health Administration (OSHA) regulates workplace exposure.

Because the United States has small chromite ore reserves and a small reserve base, domestic supply has been a concern during every national military emergency since World War I. World chromite ore resources, mining capacity, and ferrochromium production capacity are concentrated in the Eastern Hemisphere. In recognition of the vulnerability of long supply routes during a military emergency, chromium was held in the National Defense Stockpile (NDS) since before World War II in various forms, including chromite ore, chromium ferroalloys, and chromium metal. As a result of changed national security considerations since 1991, stockpile goals have been reduced, and inventory is being sold. Material for recycling is the only domestic supply source of chromium.

The U.S. Geological Survey (USGS) has conducted mineral resource surveys of the United States to assess the potential for occurrences of chromium and other mineral resources. The National Aeronautics and Space Administration, the National Institute of Standards and Technology, the U.S. Department of Defense (DOD), and the U.S. Department of Energy conduct alternative materials research.

Domestic Data Coverage

Domestic data for chromium materials were developed by the USGS by means of the monthly "Chromite Ores and Chromium Products" and "Consolidated Consumers" consumer surveys. High-carbon ferrochromium is the most consumed chromium-containing material. Stainless and heat-resisting steel producers accounted for most of chromium-containing material consumed.

Legislation and Government Programs

The Defense National Stockpile Center (DNSC) disposed of chromium materials under its fiscal year 2005 (October 1, 2004, through September 30, 2005) Annual Materials Plan (AMP) and announced the fiscal year 2006 plan. The DNSC's fiscal year 2006 AMP set maximum disposal goals for chromium materials at 136,000 t of chromium ferroalloys, 90,700 t of chemical-grade chromite ore (or remaining inventory), 90,700 t of refractory-grade chromite ore (or remaining inventory), and 907 t of chromium metal (Defense National Stockpile Center, 2005).

The DNSC (a part of the Defense Logistics Agency) was created to reduce U.S. dependence on foreign sources for strategic and critical materials (Holder, 2005). The DNSC sells chromium materials on the open market to domestic and foreign buyers while avoiding undue market disruption and protecting against avoidable monetary loss. The DNSC sets annual sales ceilings by material in the AMP based on advice from the Market Impact Committee, which comprises representatives from several Federal Government agencies. The DNSC had set a sales ceiling of 140,000 t of ferrochromium in fiscal year 2003 with sales of 77,000 t (high-carbon, 61,000 t; low-carbon, 16,000 t); 100,000 t in each of 2004 and 2005 with sales of 100,000 t in 2004 (high-carbon, 74,000 t; low-carbon, 26,000 t); and 56,000 t in 2005 (high-carbon, 49,000 t; low-carbon, 7,000 t). The chromium metal sales ceiling was 450 t in each of the fiscal years 2003, 2004, and 2005. Actual sales of chromium metal were 103 t in 2003 (all of which was aluminothermic), 447 t in 2004 (384 t aluminothermic, 64 t electrolytic), and 479 t in 2005 (73 t aluminothermic, 406 t electrolytic). In April 2005, the DNSC held 355,000 t of high-carbon ferrochromium, 179,000 t of low-carbon ferrochromium, 4,500 t of electrolytic chromium metal, and 1,600 t of aluminothermic chromium metal in inventory.

Production

The major marketplace chromium materials are chromite ore, foundry sand, chromium chemicals, ferroalloys, and metal. In 2005, the United States produced chromium ferroalloys, metal, and chemicals, but no chromite ore. The United States is a major world producer of chromium metal and chemicals and of stainless steel (the major end use of chromium).

Oregon Resources Corporation [a subsidiary of Resource Finance and Investment Ltd. (Bermuda)] planned to start chromite ore production in 2006 at its surface mine in Coos County, OR (Resource Finance and Investment Ltd., 2006§[1]). Oregon Resources began construction on a 10-metric-ton-

[1]References that include a section mark (§) are found in the Internet References Cited section.

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per-hour plant using spiral separators, high tension rolls, electrostatic separators, and rare earth magnets to separate and purify chromite, garnet, and zircon minerals. Oregon Resources reported proven reserves of 1.27 million metric tons (Mt) of mineral sands (proven plus probable reserves of 1.9 Mt; geologic resources of 6.4 Mt) that contained an average of 13% chromite. The company estimated that it would produce about 41,000 metric tons per year (t/yr) of foundry-grade chromite (Industrial Minerals, 2005).

Environment

The OSHA reviewed occupational exposure limits for hexavalent chromium and issued for public comment a proposed rule to reduce such exposure. The proposed exposure set an 8-hour time-weighted average exposure limit of 1 microgram per cubic meter (Dobos, 2005§). The new rule was expected to become final in 2006.

Huvinen (2006) studied the effect of chromium on human health. The study found that, for metallic chromium and chromium oxide, labeling and further testing are not required; however, basic chromium sulfate should be labeled, further risk testing should be done, and data gaps identified. The study found no long-term health effects for workers in the stainless steel or ferrochromium industries or for consumers of stainless steel.

Prices

Chromium materials are not openly traded. Purchase contracts are confidential between buyer and seller; however, trade journals report composite prices based on interviews with buyers and sellers, and traders declare the value of materials they import or export. Thus, industry publications and U.S. trade statistics are sources of chromium material prices and values, respectively.

Based on Platts Metals Week reported prices, the high-carbon ferrochromium price peaked at $0.76 per pound of contained chromium in 2005, surpassing the $0.72 per pound reached in 2004, and then dropped to $0.60 per pound (Ward, 2006). The price of low-carbon ferrochromium peaked at $1.10, not quite as high as the $1.17 as in 2004, and then dropped to about $0.90 per pound. Decreasing production of stainless steel in the second half of 2005 was cited as the major cause of ferrochromium price decrease—reduced stainless steel production resulted in reduced demand for ferrochromium, which resulted in a reduced price for ferrochromium. Elimination of ferrochromium production cutbacks and additional production capacity starting up contributed to the price decrease. The cost of ferrochromium was forecast to rise based on increasing costs in South Africa (resulting from factors of production, such as labor, transportation, and electrical energy; currency exchange rates; and compliance with environmental regulations), the major producer of high-carbon ferrochromium.

The average South African rand exchange rate, a significant factor in the price of chromite ore and ferrochromium, declined to R6.4 per U.S. dollar in 2005 from R10.5 per U.S. dollar in 2002 (Pacific Exchange Rate Service, 2006§).

Foreign Trade

The U.S. International Trade Commission determined that degassed chromium metal from Japan was dumped on the U.S. market. An antidumping duty of 129.32% was to be imposed in 2006 (U.S. Department of Commerce, International Trade Administration, 2005).

World Industry Structure

The chromium industry comprises chromite ore, chromium chemicals and metal, ferrochromium, stainless steel, and chromite refractory producers. Several trends are taking place simultaneously in this industry. The industry has eliminated excess chromium chemical production capacity, concentrating on production growth in surviving plants. Chromite refractory use has been declining; however, foundry use has been growing slowly. The amount of chromite ore from independent producers is declining, while that from vertically integrated producers is increasing. In other words, chromite ore mines tend now to be owned and operated by ferrochromium or chromium chemical producers. This trend is associated with the migration of ferrochromium production capacity from stainless-steel-producing countries to chromite-ore-producing countries, a trend that is nearly complete. While ferrochromium production capacity was rationalized in historically producing countries, which usually have been stainless-steel-producing countries, new furnaces or plants were constructed in chromite-ore-producing areas. The electrical power and production capacities of submerged- electric arc furnaces (EAF) used to produce ferrochromium have been increasing. Furnaces built recently have an electrical capacity in the tens of megavoltamperes. When ferrochromium plants were first built, furnaces rated in the low kilovoltampere range were common.

Production process improvements, such as agglomeration of chromite ore, preheating and prereduction of furnace feed, and closed-furnace technology, have been retrofitted at major producer plants and are being incorporated in newly constructed plants. Since the introduction of post-melting refining processes in the steel industry after 1960, there has been a shift in production to high-carbon ferrochromium from low-carbon ferrochromium. After years of ferrochromium production, slag stockpiles have built up. Recently developed processes efficiently recover ferrochromium from that slag, and processes have been or are being installed at heritage plant sites. In South Africa, the major chromite-ore- and ferrochromium-producing country, two trends are emerging—ferrochromium plants are being developed in the western belt of the Bushveld Complex, and ferrochromium production processes are being designed to accommodate chromite ore byproduct recovery from platinum operations.

Capacity.—Rated capacity is defined as the maximum quantity of product that can be produced in a period of time at a normally sustainable long-term operating rate, based on the physical equipment of the plant and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and plants temporarily closed that can be brought into production

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within a short period of time with minimum capital expenditure. Because not all countries or producers make information about production capacity available, historical chromium trade data have been used to estimate production capacity. Reported production capacity changes result from both facility changes and knowledge about facilities. New information about a facility may result in the reevaluation of production capacity for that facility. Production capacities have been rated for the chromite ore, chromium chemical, chromium metal, ferrochromium, and stainless steel industries (table 7).

Production.—World chromite ore production in 2005 was about 19.1 Mt, of which about 93.4% was produced for the metallurgical industry; 3.1%, for the chemical industry; 2.8%, for the foundry industry; and 0.7%, for the refractory industry (International Chromium Development Association, 2006, p. 1).

Stainless Steel.—In 2005, world stainless steel production was 24.330 Mt, a decrease of 1.0% compared with that of 2004 (International Stainless Steel Forum, 2006§).

Nippon Steel and Sumikin Stainless Steel Corp. (NSSC) was the leading stainless steel producer in Japan with annual production capacity of 1.1 million metric tons per year (Mt/yr) distributed among its Hikari, Kashima, and Yawata plants (Omura, 2006). NSSC at Yawata produced raw low-interstitial ferritic grades of stainless steel that had formability and corrosion resistance properties between those of conventional ferritic grades and austenitic grades. The chromium content of interstitial ferritic grades ranged from 17% to 30%. This material was used in building materials, electric appliances, electric water heaters, kitchen utensils, molding, roofing, and water tanks. Omura also described the attributes and applications of various grades of ferritic stainless steel.

Molybdenum is used along with nickel and chromium to achieve corrosion resistance and toughness in stainless steel needed for chemical transportation, commercial kitchen, industrial process, and outdoor objects (such as sculptures, furniture, and signage). Molybdenum and chromium are also used in nickel-base alloys for stationary and jet engine turbines. World molybdenum production in 2004 was 180,000 t, 86% of which was consumed in metallurgical applications—23% to 33% for stainless steel and the balance in other metallurgical uses (Kinsman, 2006). This use of molybdenum in stainless steel assumed that 0% to 30% of molybdenum supply for stainless steel comes from scrap material feed. Stainless steel typically contains 2% molybdenum.

Stainless Steel Scrap.—The price of nickel in 2005 reached a historically high value, partly because of speculative investment. Nickel-containing stainless steel scrap availability increased in response to increasing nickel price until mid-2005 when stainless steel producers perceived a production slow down and stainless steel scrap suppliers used up their inventories. As a result, stainless steel scrap supply declined in the latter half of 2005 to 83% of that of the first half (Terörde, 2006). The trend in stainless steel scrap availability typically follows that of nickel price. The external austenitic scrap ratio—the consumption of external austenitic stainless steel scrap relative to production—ranged from 42% to 49% and averaged 44% compared with about 36% in 2001. External austenitic scrap ratios varied among regions between 2003 and 2005, as follows: United States, 61% to 69%; Europe, 36% to 46%; Japan, 33% to 40%; and the rest of Asia, 34% to 54%. World stainless steel production in 2005 was estimated to be 24.5 Mt, of which 15.4 Mt was austenitic, 6.4 Mt was ferritic, and 2.7 Mt was low-nickel, chromium-manganese stainless steel. Internal stainless steel scrap accounted for 3.2 Mt, and external, 7.1 Mt, leaving 14.2 Mt of stainless steel for which primary chromium units were required—equivalent to about 4.5 Mt of ferrochromium. From 2003 through 2005, secondary chromium units have accounted for 27% to 28% of chromium supply for stainless steel production.

Chromium Metal.—Major chromium metal producers included Russia and the United States (by the electrolytic process) and China, France, Russia, and the United Kingdom (by the aluminothermic process).

World chromium metal consumption reached 35,000 t (31,500 t aluminothermic and 3,500 t electrolytic) in 2005 (Lofthouse, 2006). Western world consumption ranged from 20,000 to 22,000 t between 1997 and 2001. The increasing consumption of chromium metal was attributed to strong superalloy demand for aerospace and oil exploration applications. Chromium metal was supplied by Europe (33.7%), Russia (31.4%), China (24.6%), and others (10.3%) in 2005, while it was used by North America (38.6%), Europe (31.4%), Far East (17.2%), China (7.1%), Russia (4.3%), and other (1.4%). Superalloys used in aerospace, automotive, electrical, oil and gas, petrochemical, pollution control, power generation, and process chemical applications accounted for most chromium metal demand.

World chromium metal consumption in 2005 was about 28,000 t compared with 24,000 t in 2004 and 23,000 t in 2003. Chromic oxide supply was identified as a potential constraint on chromium metal production (TEX Report, 2005c).

World Review

Albania.—Darfo S.p.A (Italy) produced chromite ore and ferrochromium. Darfo planned to double ferrochromium production capacity by 2008 (Metal-Pages, 2005a§).

Australia.—Pilbara Chromite Pty. Ltd. (a subsidiary of Consolidated Minerals Limited) produced 241,756 t of chromite ore in financial year 2005 (July 1, 2004, through June 30, 2005) compared with 243,221 t in 2004. Pilbara's chromite ore grade was 42% chromic oxide (Cr_2O_3); production capacity was 250,000 t/yr (Consolidated Minerals Limited, 2005§).

Brazil.—In 2004, Brazil produced 593,476 t of chromite ore (42.6% Cr_2O_3), exported 37,341 t of chromite ore (16,057 t of Cr_2O_3 content), and imported 44,763 t (20,143 t of Cr_2O_3 content). Brazil produced from a chromite ore reserve containing about 7.624 Mt Cr_2O_3-content. In 2004, Brazil produced 216,277 t of chromium ferroalloys, imported 13,480 t of ferrochromium, and exported 659 t (Gonçalves, 2006). Based on production of chromite ore and trade of chromite ore and chromium ferroalloys data reported above, Brazilian chromium apparent consumption in 2004 was 325,000 t. Expansion of Brazilian stainless steel production capacity was expected to increase domestic demand for domestically produced ferrochromium.

China.—Based on reported chromite ore production and trade of chromite ore and chromium ferroalloys and metal data (TEX

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Report, 2006a, b, e), China's chromium apparent consumption in 2005 was 1.03 Mt, more than double that of 2003. China applied an export tax rebate, a domestic value added tax, and an export duty to chromium materials. On chromium, the export tax rebate was 13%, and the domestic value added tax was 17%. On ferrochromium, the export tax rebate was zero, the domestic value added tax was 17%, and the export duty tax was 5%.

China's demand for chromium ferroalloys increased along with its increasing production of stainless steel. China produced about 3.20 Mt of stainless steel in 2005 compared with 2.80 Mt in 2004. The increase in chromite ore imports and decrease in ferrochromium imports means that the increased demand for ferrochromium was met from domestic production, which posed problems for China because ferrochromium production is energy intensive, and China experienced shortfalls in energy supply. Many heritage ferroalloy plants were small, less energy efficient facilities than larger, more modern plants, and not as environmentally friendly as modern plants could be. To address these problems, the National Development and Reform Commission reviewed China's ferroalloy producing plants in the following five areas: technology and equipment, environmental protection, power consumption, resource consumption, and safety facilities (TEX Report, 2006m, n).

The Eurasian Industrial Association (Kazakhstan) planned to acquire Asmare Iron and Steel (a ferrochromium-silicon producer in Kuytun) located about 400 km from Kazakhstan. Asmare operated two 12,500 kilovoltampere furnaces (Metal-Pages, 2005b§).

China's stainless steel production was projected to grow to about 4.4 Mt in 2007 from 2.3 Mt in 2002, and ferrochromium production was projected to grow to 700,000 t in 2005 from 330,000 t in 2002, resulting in China's potential demand for chromite ore growing to 2.025 Mt from 1.14 Mt. China is the leading ferrochromium demand growth market, and Chinese ferrochromium production capacity will grow to meet Chinese demand as long as the price of chromite ore is sufficiently low. Kazakhstan's proximity to China gives providers an advantage, spuring interest in supplying China's chromium demand (Mirakhmedov, 2006).

China's stainless steel consumption rose to about 5.2 Mt in 2005 from 325,000 t in 1991, an average annual growth rate of 22%. During the same time period, stainless steel production rose to about 3 Mt from 260,000 t, an average annual growth rate of 19%. Among the issues facing China's stainless steel industry are rapid production capacity growth, excessive investment, inconsistent product quality, and the production of nonstandard 200 series products (International Stainless Steel Forum, 2005). It was estimated that, by 2010, China's stainless steel production capacity will exceed 16.3 Mt/yr and consumption will be 8 to 10 Mt/yr, at which time China will account for 45% of world stainless steel production and 30% of world consumption. China was expected to promote the use of ferritic grades owing to the high price of nickel (Wang, 2006).

Finland.—Outokumpu Oyj produced 572,000 t of marketable chromite ore from 1.1 Mt of run-of-mine ore and 235,000 t of ferrochromium in 2005 compared with 580,000 t of chromite ore from 1.2 Mt of run-of-mine ore and 264,000 t of ferrochromium in 2004. Outokumpu reported 2004 chromite ore proved reserves of 41 Mt grading 25% Cr_2O_3, indicated resources of 13 Mt grading 29% Cr_2O_3; and inferred resources of 73 Mt grading 29% Cr_2O_3. Outokumpu reported 1.65 Mt/yr stainless steel melting capacity at its Tornio Works (Outokumpu Oyj, 2006§).

Outokumpu studied the ferrochromium production process at its operation to improve sustainability by accounting for the increased cost and reduced quality of raw materials, increased energy cost, stricter environmental regulations, and demand for better working conditions (Daavittila, Honkaniemi, and Jokinen, 2004). Outokumpu found that the cost distribution of ferrochromium production in Europe was chromite ore, 30%; electricity, 30%; reducing agent, 20%; and other, 20%. Natural laws set the minimum amounts of chromite ore, reducing agent, and energy required to produce ferrochromium; however, real process inefficiencies resulted in material and energy use above these minima. Changes in production technology have improved production efficiency and profitability of ferrochromium operations. In particular, the historical movement from using lumpy ore to pelletized ore feed, from open to semiclosed to closed furnaces, from lower power to high-power furnaces, and the introduction of air and water cleaning processes has improved sustainability. Outokumpu identified the availability of furnace and other production equipment as the major profitability issue facing the ferrochromium industry, especially for larger furnaces. In addition, profitability can be improved by increased use of lower cost raw materials, increased furnace size, more efficient energy use and recovery, greater automation, and stricter environmental control.

The 21 European stainless steel producers operating in 1976 consolidated to 4 producers in 2001; the world stainless steel compound annual demand growth rate was 5.5% from 1980 through 2002; and Outokumpu was Europe's third ranked stainless steel producer (as measured by slab capacity) (Kaitue, 2005).

France.—Arcelor S.A. (a multinational company) reported 1.741 Mt of raw stainless steel production in 2005 compared with 2.453 Mt in 2004 (Arcelor S.A., 2006§). Arcelor's crude stainless steel production grew at more than 5% per year from 1978 through 2004; austenitic grades were more popular than ferritic grades. The popularity of grades may be changing owing to the increased cost of austenitic grades that result from the increased nickel and molybdenum prices (cost) (Charles, 2005).

India.—In fiscal year 2004-05 (April 1, 2004, through March 31, 2005), 20 mines collectively produced 3,639,848 t of chromite ore compared with 2,904,809 t of chromite ore in 2003-04 from a chromite ore recoverable reserve of 97.076 Mt (Indian Bureau of Mines, 2006§). Chromite ore exports were 745,119 t in 2004-05 compared with 1,116,401 t in 2003-04. Imports were 62,467 t in 2002-03 compared with 66,138 t in FY 2001-02. Ferrochromium production was reported to be 380,528 t in 2002-03 compared with 302,109 t in 2001-02. Exports were 62,467 t in 2002-03 compared with 66,138 t in 2001-02, and imports were 11,868 t in 2002-03 compared with 7,339 t in 2001-02 (Indian Bureau of Mines, 2005, p. 467, 482, 485). Based on this information, Indian apparent chromium consumption was 871,000 t in 2004-05 compared with 538,000 t in 2003-04 and 618,000 t in 2002-03.

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Indian chromium ferroalloy production was 396,700 t in 2002-03, 302,100 t in 2001-02, 381,900 t in 2000-01, 313,800 t in 1999-2000, and 305,300 t in 1998-99 (Roy and Kumar, 2004). Capacity utilization was estimated to be 80% in 2004. Exports were 91,000 t in 2002-03, 101,000 t in 2001-02, 171,000 t in 2000-01, 161,000 t in 1999-2000, and 158,000 t in 1998-99.

Jindal Stainless Ltd., a stainless steel and ferrochromium producer, expanded its annual stainless steel and ferrochromium production capacity. Jindal produced ferrochromium at Vizag and developed a greenfield operation in Orissa State to produce ferrochromium and stainless steel. The Vizag plant had a high-carbon ferrochromium production capacity of 40,000 t/yr. The Orissa plant started the operation with an annual ferrochromium production capacity of 80,000 t/yr and planned to start a second 80,000-t/yr furnace in 2006. A 500-megawatt (MW) captive powerplant was to be installed that could accommodate high-carbon ferrochromium production of 250,000 t/yr and stainless steel production of 1.6 Mt/yr (Jindal Stainless, 2006§).

IMFA Group [comprising Indian Charge Chrome Ltd. (ICCL), an export-oriented producer, and Indian Metals and Ferro Alloys Ltd. (IMFA), a domestic-oriented producer] is integrated from chromite ore mining through ferrochromium production, including thermoelectric power generation. IMFA completed installation of a 27-megavoltampere (MVA) furnace with ferrochromium production capacity of 35,000 t/yr at its Choudwar, Orissa, plant at a cost of about $11 million, bringing its installed electrical capacity to 157 MVA. IMFA planned to add a 27-MVA and a 48-MVA furnace and a 120-MW powerplant at Choudwar. IMFA Group reported fiscal year 2004-05 chromite ore production to be 252,189 t, and ferrochromium production, 105,211 t compared with 77,746 t in 2003-04. ICCL planned to open captive chromite mines in Mahagiri, Orissa, upon receipt of environmental permits (Metal-Pages, 2005g§; IMFA Group, 2006§).

Electrical power availability and coal as a reducing agent limited ferrochromium production. Indian ferrochromium production power consumption was 3,800 kilowatthours per metric ton, which accounted for 45% of total production cost. Labor productivity was about one-half that of a South African plant and one-fifth that of a Finish one. Raw material transportation and power and reductant costs, small plant size, and production automation were reported to be challenges to the Indian production increasing to meet growing demand in China and India (Roy and Kumar, 2004).

Iran.—Iran's Ministry of Industry and Mines completed the conversion of a ferrosilicon smelter at Sabzevar, Korasan-e Razavi Province to ferrochromium production. The Sabzevar smelter had a 20-MVA furnace with high-carbon ferrochromium production capacity of 20,000 t/yr and planned to use about 78,000 t/yr of locally mined chromite ore from Neishabur and Sabzevar (Pyromet Technologies (Pty.) Ltd., 2005§).

Japan.—In 2005, Japan imported 954,383 t of high-carbon and 65,133 t of low-carbon ferrochromium; 108,074 t of stainless steel scrap;103,778 t of chromite ore; 4,965 t of chromium metal; and 2,160 t of ferrochromium silicon. Japan produced 3,584,879 t of stainless and heat-resisting steel (TEX Report, 2006c, d, f-k, o, q). Based on available data reported above, Japanese chromium apparent consumption was 599,000 t in 2005.

Kazakhstan.—Kazchrome reported chromite ore production of 3.566 Mt in 2005 compared with 3.26 Mt in 2004, and high-carbon ferrochromium production of about 835,000 t in 2005 compared with 780,000 t in 2004. In addition to high-carbon ferrochromium production, Kazchrome produced 40,000 t of medium-carbon and 30,000 t of low-carbon ferrochromium, 42,000 t of ferrochromium-silicon, and 1,200 t of chromium metal in 2004. Chromite ore was produced at Donskoy Mine, Aqtobe Oblysy; ferrochromium at Aksu, Pavlodar Oblysy, and Aktobe, Aqtobe Oblysy, and chromium metal at Aktobe. Kazchrome completed construction of a pelletizing plant based on Outkumpu technology. The pelletizing plant was expected to start in 2006 with a production capacity of 700,000 t/yr (Sittard, 2005; TEX Report, 2005d; Metal-Pages, 2005f§; Ryan's Notes, 2006b).

Oriel Resources plc (United Kingdom) planned to develop the Voskhod chromite deposit in Aqtobe Oblysy. Voskhod had 18.7 Mt of indicated chromite ore resources grading 46.2% Cr_2O_3. The deposit was discovered in 1963 in the Kemirsayskiy Massif, located about 3 kilometers (km) south of Donskoy GOK, 100 km east of the city of Aktobe, and 30 km east of the city of Khromtau. The deposit comprises one large lens of massive to disseminated chromite at a depth of 98 to 440 meters (m). A preliminary assessment called for underground mining by the sublevel caving method to produce about 700,000 t/yr at an average grade of 43.7% Cr_2O_3 for about 25 years. The plant would include crushing, milling, dense media separation, and gravity concentration to produce 322,000 t/yr of lumpy ore at 49% Cr_2O_3 and 189,000 t/yr of concentrate at 55% Cr_2O_3. Construction was planned to start in 2006; production, in 2007 (Oriel Resources plc, 2005§).

Korea, Republic of.—Korea imported 511,769 t of ferrochromium (476,248 t of high-carbon and 35,521 t of low-carbon) in 2005. Changwon Specialty Steel Co., Ltd. started construction of a 30-t argon-oxygen-decarburization furnace. Once installed, Changwon's stainless steel production capacity would be about 275,000 t/yr. Based on the ferrochromium data reported above, Korean chromium apparent consumption was 285,000 t in 2005(TEX Report, 2006l).

Kosovo.—The Kosovo Trust Agency sought foreign investment in chromite ore mining.

Madagascar.—Pan African Mining Corp. started exploration of chromite deposits around the Zafindravoay chrome property where the Government mined chromite until 1987 (Olian, 2005§).

Pakistan.—Pakistan produced chromite ore, which it planned to trade with China. Al Abbas Industries built a ferroalloy plant at Dhabeji Industrial Park, and planned to produce ferrochromium (Metal-Pages, 2005c§).

Russia.—Russia exported 419,469 t of ferrochromium in 2005 (243,005 t of high-carbon, 176,465 t of low-carbon) compared with 271,471 t in 2004 (109,840 t of high-carbon, 161,631 t of low-carbon) (TEX Report, 2006p).

Chelyabinsk Electro Metallurgical Combine (ChEMK) in Kemerovo Oblast operated the Kongor Chrome Mine and the JSC Kuznetskie Ferrosplavy. Kongor Chrome Mine, near the settlement of Kharp in Yamalo-Nenetskiy Autonomous Region, is part of the Tsentralnoye chromite deposit in the Rayiz Mountain range north of the Arctic Circle. The mine has 6 Mt of reserves and 100 Mt of resources. Kongor produced 800,000 t grading

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40% Cr_2O_3 in 2005 and planned to produce 1.4 Mt in 2006 and 1.5 Mt in 2007. ChEMK was constructing a concentrator near the mine. ChEMK produced 275,000 t of high-carbon ferrochromium and 130,000 t of medium carbon ferrochromium at Chelyabinsk Electrometallurgical Combine in Chelyabinsk, Chelyabinsk Oblast, and at JSC Kuznetskie Ferrosplavy in Novokuznetsk, Kemerovo Oblast. With the development of its Konor Mine, ChEMK planned to shift ferrochromium production to Kuznetskie, which had the capacity to produce 450,000 t/yr of high-carbon ferrochromium and 135,000 t/yr of low-carbon ferrochromium (Lundman, 2006).

Russian Chrome 1915 (formerly Khrompik Company) in Ekaterinburg, Sverdlovsk Oblast, was Russia's leading chromium chemical producer, having a production capacity of about 30,000 t/yr of chromium chemicals. Company ownership was split equally between Kermas Group (United Kingdom) and Luigi Stoppani Company (Italy). Kermas planned to sell its share to Klyuchevsky Ferroalloy Plant. Russian Chrome provided about 4,800 t/yr of chromium oxide to Klyuchevsk (Kommersant Daily, 2006§).

Kluchevsky Ferroalloy Plant in Sverdlovsk Oblast produced chromium ferroalloys and aluminothermic chromium metal. Kluchevsky produced 9,188 t of chromium metal in 2004 from a capacity of 9,800 t/yr (Metal-Pages, 2005e§).

Serov Ferroalloy Plant produced between 40,000 and 50,000 t of low-carbon ferrochromium in 2004 from a capacity of 70,000 t/yr. Kermas Group (the majority owner of Serov) planned to sell its share to International Mineral Resources (Metal-Pages, 2006c§).

SZFK-Northwest Ferroalloys Company (owned about one-third by IST and two-thirds by IPH Polychrom Holding B.V.) planned to complete a ferrochromium plant at Tikhvin, Leningrad Region, about 200 km from St. Petersburg. The plant's production capacity was planned to be 140,000 t/yr, comprising four 16.5-MVA furnaces. Construction of the plant was expected to be completed in 2006 at a cost about $97.2 million. SZFK planned to first smelt imported chromite ore and then to switch over to chromite ore mined by the company's subsidiary Karelmet Joint Stock Company, which planned to develop the Agonozerskoye chromite deposit in Karelia Region (Metal-Pages, 2006b§).

The Republic of Bashkortostan put the 20-year rights to the Apshakskaya and Klyuchevskaya chromite ore properties up for auction at a starting price of about $7,000 each. Apshakskaya had resources of 10,500 t; Klyuchevskaya had reserves of 35,000 t (Metal-Pages, 2006a§).

South Africa.—The ferrochromium industry has been growing at about 5% per year, which is equivalent to production from two to three new furnaces per year. National issues currently facing the South African chromium industry include environmental concerns over chromium emissions and dust generation and adequacy of electrical power supply, transportation facilities, and shipping facilities. Black empowerment legislation requires 26% ownership by formerly underrepresented groups by 2014. Black empowerment and the sale of Samancor's Chrome Division resulted in ownership realignments among chromite ore and ferrochromium producers, while anticipated demand increases resulted in new chromite ore mines, ferrochromium furnace renovations, and new furnaces that increased production capacity and decreased pollution.

The South African ferrochromium industry is critically dependent on the South African electrical power generating authority (Eskom), the transportation authority (Transnet), and the port authority (National Ports Authority of South Africa) to provide the infrastructure necessary to produce, process, and export chromite ore and ferrochromium. Eskom provides most of South Africa's electricity from coal-fired powerplants. Since 1994, Eskom has connected 3.2 million homes to the national power grid. Eskom reported that it is embarking on a 5-year, R93 billion program to increase electrical power generation capacity. During the next 20 years, Eskom planned to reopen powerplants mothballed in the 1980s, to develop hydropower and liquid natural gas, to improve efficiency in generation and use, and to enter into partnerships (Visagie, 2006). The National Ports Authority reported that Durban (handling 24% of cargo), Richards Bay (50%), and Saldanha (19%) were South Africa's major ports. The National Ports Authority planned to complete constructing the Port of Ngqura by 2020 to accommodate very large, container-carrying vessels and to add bulk cargo capacity later. The National Ports Authority has moved its national development plan forward by 10 years to meet demand for its services (Jones, 2006).

In 2004, South Africa produced 7.645 Mt of chromite ore from which it produced 2.965 Mt of chromium ferroalloys and exported 0.513 Mt of chromite ore and 2.617 Mt of ferrochromium (Kweyama, 2005). Based on available data reported above, South African chromium apparent consumption was 708,000 t in 2004. Since 1994, chromite ore export sales as a fraction of production have decreased to less than one-tenth from about one-fourth, while chromite ore production has more than doubled.

Chrome Corporation (Australia) took over the Ruighoek Mine formerly owned by Batlhako Mining Limited. The mine is located in the North-West Province west of Sun City; chromite ore was last produced in 1993 from the LG6 seam. The company planned to produce 300,000 t/yr of chromite ore from the LG6 seam equally divided between surface and underground operations from an indicated resource of 5 Mt and inferred resource of 23 Mt (Creamer, 2005).

Samancor Chrome (owned 60% by BHP Billiton and 40% by Anglo American plc) operated chromite ore mines and ferrochromium smelters until midyear, when it was purchased by Kermas Group (United Kingdom) for $469 million. Kermas is a vertically and horizontally integrated chromium materials producer. Kermas also owned Serov and Chrome 1915 in Russia, Elektrowerk Weisweiler GmbH (EWW) in Germany, and chromite ore mines in Turkey. EWW and Serov produced low-carbon ferrochromium. Samancor comprised five business units—Eastern Chrome Mines and Western Chrome Mines, producing chromite ore, and Ferrometals, Middleburg Ferrochrome, and Tubatse, producing ferrochromium. Samancor renovated the Eastern Chrome Mines, significantly extending their operating life (Konchar, 2005; Lanham, 2005).

International Ferrometals Ltd. (IFM), an Australian company formerly known as Transvaal Ferroalloys, raised one-half of the R2.12 billion it needed to develop the Buffelsfontein chromite deposit and construct a ferrochromium plant. Buffelsfontein

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had 28.6 Mt of chromite ore reserves grading 36.6% Cr_2O_3 and inferred resources of 29.6 Mt at the same grade (Ryan's Notes, 2005b; Metal-Pages, 2005d§). IFM gained access to the Sky deposit from Purity Metals Holdings. The Sky deposit held 28.4 Mt of chromite ore reserves grading 36.6% Cr_2O_3 and 29.6 Mt of inferred reserves at the same grade (Ryan's Notes, 2005c). IFM planned to produce 267,400 t/yr of ferrochromium from chromite ore from the MG1 and MG2 seams of the Bushveld Complex in North-West Province. The operation would include a mine, a pelletizing plant (400,000 t/yr capacity), and two 66-MVA furnaces, with the potential to add two more furnaces. IMF contracted Pyromet to build the plant; ferrochromium production was expected to start in 2007 (Cromberge, 2005).

ASA Metals (Pty.) Ltd. produced chromite ore and ferrochromium at Burgersfort, North-West Province. ASA operated two EAF and a pelletizing plant with pellet production capacity of 500,000 t/yr and ferrochromium production capacity of 240,000 t/yr. ASA planned to add two more furnaces and a pelletizing plant at a cost of R1.5 billion that would double annual ferrochromium production capacity. ASA also planned to add 800,000 t/yr of chromite ore production capacity near to its Dilokong Mine, raising its annual chromite ore production capacity to 1.15 Mt/yr (Ryan's Notes, 2005a; TEX Report, 2005a).

Columbus Stainless Steel (Pty.) Ltd. produced stainless steel in Middelburg, Mpumalanga Province. Melt shop production was about 718,094 t in 2004 compared with 643,000 t in 2003, 550,000 t in 2002, and 516,000 t in 2001 (Acerinox, S.A., 2005§).

Feralloys Limited (owned by Assmang Ltd.) produced chromite ore at the Dwarsrivier Mine and ferrochromium at the Machadodorp plant. Feralloys' ferrochromium production capacity was 300,000 t/yr from four furnaces. The Dwarsrivier Mine had a production capacity of 600,000 t/yr, and the company planned to increase capacity to 1 Mt/yr. Dwarsrivier started underground mining. Feralloys started testing chromite ore from the Lionore Mine, where nickel and chromite ore were produced (TEX Report, 2005b).

Tata Iron and Steel Co., Ltd. (India) announced plans to build a ferrochromium plant at Richards Bay, Kwazulu-Natal Province, a port city removed from South Africa's chromite mines. Tata is a major chromite ore and ferrochromium producer in India. Initial production capacity at the plant was planned to be 120,000 t/yr at a cost of R600 million and with the potential to double. Construction was expected to begin in 2006 with startup in 2008 (Creamer, 2005§).

Hernic (Pty.) Ltd. produced chromite ore and ferrochromium at Brits, North-West Province. Hernic contracted Outokumpu to install a 75-MVA closed furnace with equipment to pelletize, sinter, and preheat furnace feed. The new furnace, the fourth at the plant, started operation in 2005 and was expected to operate at the full production rate of about 160,000 t/yr in 2006, consuming 66 to 67 MW. Hernic planned to reconstruct its old open furnaces as semiclosed furnaces near the Bokontein deposit, about 10 km from the current plant (Mitsubishi Corporation, 2005§).

Xstrata S.A. (Pty.) Ltd. reported operating 5 chromite ore mines and 18 ferrochromium furnaces. Xstrata produced 3.604 Mt of chromite ore in 2005, about 72% of capacity, compared with 4.220 Mt in 2004. In 2005, Xstrata's chromite ore production by mine was as follows: Kroondal, 1.863 Mt; Thorncliffe, 1.210 Mt; Waterval, 445,000 t; Horizon, 52,000 t; and Boshoek, 34,000 t. In 2004, Xstrata's chromite ore production by mine was as follows: Kroondal, 2.134 Mt; Thorncliffe, 1.274 Mt; Waterval, 405,000 t; Boshoek, 253,000 t; Horizon, 131,000 t; and Chrome Eden, 23,000 t. Xstrata reported ferrochromium production of 1.290 Mt in 2005, about 80% of capacity, compared with 1.489 Mt in 2004. In 2005, Xstrata's ferrochromium production by plant was as follows: Rustenburg, 383,000 t; Lydenburg, 374,000 t; Wonderkop, 333,000 t; Bosheok, 196,000 t; and Gemni plant, 4,000 t. In 2004, Xstrata's ferrochromium production by plant was as follows: Lydenburg, 393,000 t; Rustenburg, 393,000 t; Wonderkop, 311,000 t; Bosheok, 218,000 t; and Gemni plant, 173,000 t.

Xstrata announced plans to start construction on a new smelter with production capacity of 336,000 t/yr from two 63-MVA furnaces at a cost of $270 million; production would begin in 2007. The new plant would use Premus technology developed by Xstrata at its Lydenburg plant.

Merafe Resources Limited, joint-venture partner of Xstrata at the Boshoek plant, purchased Samancor's share of the Wonderkop plant, which Samancor held in joint-venture partnership with Xstrata. The purchase made Merafe and Xstrata joint-venture partners in two ferrochromium plants, Bosheok and Wonderkop. Merafe and Xstrata purchased chromite ore resources from Samancor in the Krondal and Marikana mining areas. The resources were near Xstrata's existing Waterval and Kroondal Mines. Xstrata and Merafe planned to build a 1.2-Mt/yr agglomeration plant, comprising two production lines using Outokumpu technology, at a cost of $125 million for sintering and pelletizing chromite ore feed for the Wonderkop and Rustenburg operations. Xstrata entered a joint-venture agreement with Anglo American Platinum Corp. Ltd., on the Mototolo project in which byproduct chromite tailings from the Bushveld UG2 seam would be agglomerated at Wonderkop plant. Xstrata had a production capacity of 1.6 Mt/yr of chromite ore from reserves of 51 Mt (Xstrata Plc., 2005§).

Sudan.—Sudan reported chromite ore resources at the Ignessa Hills area in Blue Nile State, the Qala En Nahal area, the Eastern Naba Mountains, the Red Sea Hills region, the Jebel Rahib area in Darfur State, and other areas in northern and southern Sudan. All of these deposits lay in the Ingessana massif, which is the central part of the Ingessana-Kurmuk ophiolite belt (Ministry of Energy and Mining, The Geological Research Authority of the Sudan, 1999§).

Taiwan.—Taiwan imported 255,869 t of ferrochromium (239,877 t of high-carbon and 15,992 t of low-carbon) (TEX Report, 2006r). Based on available data reported above, chromium apparent consumption was 142,000 t in 2005.

Turkey.—Etibank A.Ş. brought one furnace back into production at its Elazig smelter. The furnace had an electrical power rating of 17 MVA and high-carbon ferrochromium production capacity of 25,000 t/yr. A second furnace was to be brought back into production in 2006, and two more 30-MVA furnaces were being planned (Ryan's Notes, 2006a).

United Kingdom.—Elementis plc produced sodium dichromate at Eaglescliff, Stockton-on-Tees, England, and Castle Haynes,

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NC. Elementis planned to close one of its two sodium-dichromate-producing kilns at its Eaglescliff plant, thereby reducing chromium chemical production capacity in England by one-half to 50,000 t/yr. The company planned to stop producing chromium sulfate and chromic acid and focus on chromic oxide and sodium dichromate from which the chromic oxide is made. Eaglescliff is a supplier of chromic oxide for chromium metal production; about 1.6 t of chromic oxide is required to produce 1 t of chromium metal (Elementis plc, 2005§).

London & Scandinavian Metallurgical Co. (LSM) produced chromium metal by the aluminothermic process. LSM reported that chromium metal demand was strong owing to recovery in the aerospace industry (Metal Bulletin, 2006).

Since the 1980s, average world annual stainless steel production growth has been 5% to 6% and has most recently been driven by increasing demand from China. The recent use of stainless steel by end-use market in the United Kingdom was process industries, 23%; domestic and household, 17%; general engineering, 17%; construction, 16%; transportation, 15%; and food processing and distribution, 12%. A similar distribution for Italy yielded chemical and petrochemical industries, 20%; foodstuffs, 20%; household appliances, 18%; catering, 12%; building, 10%; transportation, 8%; energy, 5%; pharmaceuticals, 4%; and others, 3% (British Stainless Steel Association, 2004).

Vietnam.—Vietnam produced chromite ore containing 38% to 39% Cr_2O_3, which it exported to China. The Government of Vietnam licensed Viet Nam Coal and Mineral Industrial Group to construct facilities, and exploit, process, and export chromite ore (Business Finance, 2005§).

Qian Ding Special Steel [a subsidiary of Chien Shing (Taiwan)] planned to build a 720,000-t/yr stainless steel plant in Ba Ria-Vung Tau Province at a cost of $700 million. Qian Ding planned to export 80% of its production to Taiwan (Metal Bulletin, 2005c).

Zimbabwe.—Maranatha Ferrochrome (Pvt.) Ltd., Zimbabwe Mining and Smelting Company Consolidated (Zimasco), and Zimbabwe Alloys Limited produced high-carbon ferrochromium. Benscore Investments (Private) Limited purchased Zimbabwe Alloys from Anglo American for about $10 million. Mining companies were concerned that the Government of Zimbabwe would expropriate mining operations without compensation as the Government had done in the farming sector.

Current Research and Technology

Mineral Processing and Industrial Applications.—South Africa's Council for Mineral Technology (Mintek) has been conducting Government- and commercial-sponsored research and development on chromite ore and ferrochromium. Researchers at Mintek studied platinum-group-metal recovery from chromite tailings, EAF processing of stainless steel dust, and the chromium-platinum phase diagram. Mintek demonstrated a flotation procedure at the laboratory scale that separates platinum-group metals from chromite tailings and worked on a feasibility study for the production of 20,000 ounces per year of platinum from one chromite operation. Mintek participated in Mogale Alloys (Pty.) Ltd.'s stainless steel project through the Mintek wholly owned commercial subsidiary Mindev (Pty.) Ltd. Mogale commissioned a stainless steel dust agglomeration plant and started smelting a combination of chromite ore and stainless steel dust in its 40-MVA furnace at Samancor's Palmiet Ferrochrome Plant. Mogale gets stainless steel dust from the Columbus Stainless plant, which takes back part of the Mogale's chromium-nickel-containing alloy production. Mogale's ferrochromium production capacity was about 40,000 t/yr. Mintek studied direct current (DC) arc furnace ferrochromium production using chromite ore in a fluidized bed flash preheater. Preheating the chromite feed materials resulted in a 20% energy savings. Mintek studied the metallurgical characteristics, such as creep, phase diagrams, and tensile strength, of chromium-containing platinum-base alloys (platinum-aluminum-chromium and platinum-chromium-ruthenium) that could replace nickel-base superalloys. Mintek also studied the possibility of increasing the 50-MVA DC smelting electrical capacity limit imposed by the current-carrying capacity of one electrode by developing a furnace with two independently powered cathodes (South African Council for Mineral Technology, 2004§).

Research.—Johnson (2006) studied the anthropogenic chromium materials cycle at the global, regional, and country level, accounting for 98% of chromite ore and more than 99% of stainless steel production among 9 regions containing 54 countries. These countries accounted for 94% of the global gross domestic product and 77% of the world's population. The study found that chromium flow into in-use stocks was proportional to chromium flow into use by country and region. The leading flows into use (in descending order of amount) by region were Europe, Asia, and North America. The study found that metal goods and other uses and industrial machinery dominated end uses in the leading regions and industrial waste, end-of-life vehicles, and other uses dominated discard flows. Measured in contained chromium, Africa dominated world trade, while Asia dominated finished-product trade to North America.

Technology.—Chromium is used in combustion- and steam-driven electrical-power-generating turbines. Austenitic stainless steel is used for fuel injectors; 9% to 12% chromium-containing forgeable steels are used for blades; chromium-containing nickel-base alloys (superalloys) are used in hot sections. Directionally solidified alloys used in the most demanding regions contain 5% to 15% chromium (Metal Bulletin, 2005b). Chromium is supplied for these alloys (in order of decreasing quantity of chromium units consumed for superalloy production) principally by chromium metal, high-carbon ferrochromium, and low-carbon ferrochromium.

Outlook

The outlook for chromium consumption in the United States and the rest of the world is about the same as that for stainless steel, which is the major end use for chromium worldwide. Thus, the stainless steel industry performance largely determines the performance of the chromium industry in the United States and worldwide.

The trend to supply chromium in the form of ferrochromium by countries that mine chromite ore was interrupted as China became

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a major consumer of chromite ore; however, the trend was expected to continue eventually. The rising cost of ferrochromium sustained independent ferrochromium producers; however, other factors being equal, ferrochromium production is most cost effective when the ferrochromium plant is close to the chromite mine. With new efficient and reliable ferrochromium production facilities in chromite-ore-producing countries, ferrochromium capacity and production are expected to diminish in market-driven-economy countries that produce ferrochromium without nearby chromite ore resources. Other factors of production, such as electrical energy or labor costs can offset chromite ore transportation costs. Further vertical integration of the chromium industry is expected as chromite-ore-producing countries expand ferrochromium or stainless steel production capacity.

Chromite Ore.—Chromite ore production capacity is in balance with average consumption. To improve chromite ore availability and to stabilize feed material price, ferrochromium producers invest in chromite-ore-producing mines. Indeed, most chromite ore is produced under vertically integrated mine-smelter or mine-plant ownership. As platinum mining moves to chromite-bearing seams, a greater portion of chromite is likely to be supplied as byproduct from such operations. In addition, platinum may become a byproduct of some chromite operations.

Of chromite ore produced, 91% is used by the metallurgical industry; 95% of that is used to make stainless steel (Banerjee, 2006). The compound annual growth rate of stainless production from 1980 through 2004 was 5.62%, an annual growth rate that exceeds the annual growth rates of aluminum, copper, zinc, lead, and steel (excluding stainless). Assuming that future growth of stainless steel production is 3.5%, the scrap feed as a percent of stainless steel production is 30%, austenitic-to-ferritic ratio is 3:1, austenitic stainless steel averages 18% chromium, and ferritic stainless steel averages 12% chromium, in 2056, stainless steel production would be 100 Mt/yr, ferrochromium production would be 30 Mt/yr, and chromite ore production would be about 75 Mt/yr. At this growth rate, reserves in Finland, India, Kazakhstan, South Africa, Zimbabwe, and other countries would support 2004-56 cumulative production of 1,800 Mt of chromite ore. Many economic and physical factors will affect the distribution of production.

Platinum mining of the Merensky Reef in South Africa had reached depths that make platinum mining from the UG2 Reef economically competitive (Cramer, Basson, and Nelson, 2004). Unlike the Merensky Reef, the UG2 Reef contains chromite. UG2 ore contains 10% to 25% Cr_2O_3 with a chromium-to-iron ratio of 1.35:1. Chromite is recovered after the platinum is extracted at a grade of 40% to 42% Cr_2O_3 from platinum concentrator tailings. Ferrochromium smelters that pelletize their feed and the DC arc furnace can use this chromite. Chromite can also be recovered from the LG6 and MG1 and MG2 seams. Byproduct chromite from platinum mining operations could reach 21.7 Mt/yr in 2006 at a grade of 41% to 42% Cr_2O_3. For comparison, this would be more than double the chromite ore production from primary operations and enough to produce more than 7 Mt/yr of ferrochromium.

Chromium Chemicals.—Major producing countries where large sodium dichromate plants (production capacity in excess of 100,000 t/yr) operate included Kazakhstan, Russia, and the United States. Moderate-sized production facilities were located in China, Japan, Romania, South Africa, Turkey, and the United Kingdom. Small-scale local producers operated in China and India.

Chromated copper arsenate (CCA) had dominated wood preservation for consumer use until December 2003 when manufacturing ceased owing to the compounds arsenic content (Morgan, 2006). CCA use dropped to 24,500 t/yr in 2004 and 2005, which accounted for 11,600 t/yr of chromic acid consumed, from about 81,500 t/yr in 2002 and 2003, which accounted for 38,750 t/yr of chromic acid consumed. Acid copper chromate (ACC) is an arsenic-free, chromium-containing wood treatment that could gain market share abandoned by CCA. More than 98% of hexavalent chromium is converted to trivalent in the fixation process. ACC use has been estimated to increase to 54,000 t in 2007 from the current 38,000 t, which would require 27,000 to 39,000 t of chromic acid.

Nonmetallurgical chromite ore uses—chemical, foundry sand, and refractory—were strongly affected by metallurgical demand because the metallurgical industry can now efficiently use fine ore typically consumed in nonmetallurgical applications (King, 2005). Elementis Chromium, with plants in the United Kingdom and the United States, and Chrome International South Africa were major chromium chemical producers.

Ferrochromium.—Ferrochromium production is electrical energy intensive. Charge-grade ferrochromium requires 2,900 to 4,100 kilowatthours of electrical energy per metric ton of product, with efficiency varying by ore grade, operating conditions, and production process. Thus, ferrochromium plant location reflects a cost balance between raw materials and electrical energy supply.

The quarterly price of high-carbon ferrochromium reached $0.75 per pound the highest value since before 2000 (Bennett, 2005; Ali, 2006). The consumption trend of ferrochromium is like that of stainless steel production. An additional 2.3 Mt/yr of ferrochromium production capacity was planned for between 2005 and 2010, with an additional 1.8 Mt/yr under consideration. More than one-half of the planned capacity increases were to start in 2005 or 2006. Most of the planned capacity additions (1.1 Mt/yr) were for South Africa, followed by India (510 Mt/yr) and Kazakhstan (400 Mt/yr).

Since 1998, specific consumption of coke (tons of coke consumed per ton of ferrochromium produced) has increased to about 0.31 from about 0.27 and was expected to rise to 0.33 as closed furnace technology displaces semiclosed and open furnaces. Since 1990, world coke production had gone to about 425 Mt/yr, mostly from China, from about 360 Mt/yr, mostly from Europe. South African carbon reductant demand was projected to increase to more than 3 Mt/yr by 2010 (about one-half of which would be for ferrochromium production) from about 1.6 Mt/yr in 1998. Coke production capacity was being constructed in South Africa, where 450,000 t/yr of added capacity was to be commissioned in 2006 (Joubert, 2005).

Strong growth (1.9% to 8.3% per year between 2006 and 2010) in stainless steel production and increased ferrochromium demand that would be met by increased production in South Africa were forecast despite the increasing cost of production there (McLaughlin, 2006). From 2006 to 2010, an additional 1.85 Mt/yr of ferrochromium production capacity would be required to meet demand driven primarily by China. South African

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producers Xstrata and Merafe planned to meet that demand through Project Lion (a greenfield ferrochromium plant based on Premus technology that will add 1 Mt/yr of ferrochromium production capacity) and Project Bokamoso (the retrofitting of Xstrata's ferrochromium plants in the western Bushveld based on Outkumpu technology that will add 1.2 Mt/yr of agglomeration capacity). Lower specific electrical energy requirements, lower coke demand, and higher metal recovery that result from using the Premus and Outkumpu processes will offset higher production costs attributed to a stronger rand relative to the dollar and higher electrical energy and transportation costs in South Africa. The Premus process required only 2.4 megawatthours and 20% coke consumption per metric ton of ferrochromium produced, with a chromium recovery of 88%.

Stainless Steel.—Stainless steel demand was expected to grow in the long term. Short-term demand fluctuations can exceed long-term demand growth. World stainless steel production in 2005 was about the same as that of 2004; production grew in China and decreased in other geographic areas. Between 2004 and 2010, when supply and demand would be in balance in China, China's share of world stainless steel production capacity was projected to increase to 35% from 17%; however, demand was expected to grow by only 8%. That means that non-Chinese stainless steel production capacity currently being used to meet Chinese demand will become excess capacity in 2010 (Metal Bulletin, 2005a). Ferrochromium production does not limit stainless steel production because a large share of chromium in stainless steel comes from recycled stainless steel scrap. The price of those stainless steel grades that require nickel are sensitive to the nickel price.

Stainless steel production was expected to be 156 Mt in 2050, equivalent to an average annual growth rate of 4.5%, which is somewhat less that the historical growth rate of 5.9% form 1970-2005 (Pariser, 2006). As the price of nickel increases, the percentage of manganese austenitic stainless steel and ferritic stainless steel, which do not require nickel, increases at the expense of austenitic grades, which require nickel.

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TABLE 1
SALIENT CHROMIUM STATISTICS[1]

		2001	2002	2003	2004	2005
World, production, contained chromium:						
Chromite ore (mine)[2]	metric tons	3,680,000 r	4,410,000 r	4,630,000 r	5,340,000 r	5,810,000 e
Ferrochromium (smelter)[3]	do.	2,670,000	2,880,000 r	3,460,000	3,750,000 r	3,740,000 e
Stainless steel[4]	do.	3,180,000 r	3,480,000 r	3,860,000 r	4,180,000 r	4,130,000 e
U.S. supply:						
Components of U.S. supply, contained chromium:						
Domestic mines	do.	--	--	--	--	--
Secondary	do.	141,000	174,000	180,000	168,000	124,000
Imports:						
Chromite ore	do.	62,000	35,300	55,300	49,500	52,900
Chromium chemicals	do.	12,800	17,400	10,300	6,040	11,400
Chromium ferroalloys	do.	156,000	203,000	243,000	261,000	278,000
Chromium metal	do.	8,190	7,430	8,570	9,630	11,000
Stocks, January 1:						
Government	do.	825,000	706,000	643,000	560,000	466,000
Industry[6]	do.	14,400	16,700	8,390	9,870	7,900
Total	do.	1,220,000	1,160,000	1,150,000	1,060,000	951,000
Distribution of U.S. supply, contained chromium:						
Exports:						
Chromite ore	do.	20,000	7,680	32,800	14,000	13,700
Chromium chemicals	do.	13,200	10,500	9,710	14,500	18,900
Chromium ferroalloys and metal	do.	9,840	10,800	3,770	6,250	24,700
Stocks, December 31:						
Government	do.	816,000 e, 5	643,000	560,000	466,000	375,000
Industry[6]	do.	16,700	8,390	9,870	7,900 r	8,600
Total	do.	875,000	681,000	616,000	509,000 r	441,000
Production, reported:[7]						
Chromium ferroalloy and metal net production:						
Gross weight	do.	W	W	W	W	W
Chromium content	do.	W	W	W	W	W
Net shipments, contained chromium	do.	W	W	W	W	W
Consumption:						
Apparent, contained chromium	do.	344,000	479,000	532,000	555,000	511,000
Reported:						
Chromite ore and concentrates, gross weight	do.	W	W	W	W	W
Chromite ore, average Cr_2O_3	percent	45.0	45.4	45.0	45.0	45.0
Chromium ferroalloys:[8]						
Gross weight	metric tons	351,000	407,000	411,000	449,000	431,000
Contained chromium	do.	202,000	236,000	240,000	262,000	250,000
Chromium metal, gross weight	do.	5,890	5,080	5,140	5,690	7,280
Stocks, December 31, gross weight:						
Government:						
Chromite ore	do.	636,000 e, 5	339,000	235,000	135,000	73,400
Chromium ferroalloys	do.	906,000 e, 5	767,000	691,000	595,000	492,000
Chromium metal	do.	7,430 e, 5	7,220	7,120	6,670	6,190
Industry:						
Producer[9]	do.	W	W	W	W	W
Consumer:						
Chromite ore[10]	do.	W	W	W	W	W
Chromium ferroalloys[11]	do.	28,100	13,800	16,300	13,100	14,300
Chromium metal	do.	210	230	242	182	228
Prices, average annual:						
Ferrochromium, chromium content[12]	dollars per pound	$0.324	$0.317	$0.433	$0.690 r	$0.684
Standard chromium metal, gross weight[13]	do.	$4.24	NA	NA	NA	NA
Vacuum chromium metal, gross weight[13]	do.	$5.43	NA	NA	NA	NA

See footnotes at end of table.

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TABLE 1—Continued
SALIENT CHROMIUM STATISTICS[1]

		2001	2002	2003	2004	2005
U.S. supply—Continued:						
Consumption—Continued:						
Prices, average annual—Continued:						
Electrolytic chromium metal, gross weight[14]	dollars per pound	$4.50	$4.50	$4.50	$4.50	$4.50
Aluminothermic chromium metal, gross weight[15]	do.	$2.08	$2.08	$1.84	$2.27	$2.72
Value of trade:[16]						
Exports, contained chromium	thousands	$89,400	$67,600	$58,400	$80,700	$116,000
Imports, contained chromium	do.	$239,000	$256,000	$322,000	$477,000	$583,000
Net exports, contained chromium[17]	do.	-$149,000	-$188,000	-$264,000	-$397,000	-$468,000
Stainless steel:						
Production:						
Gross weight[18]	metric tons	1,820,000	2,190,000	2,220,000	2,400,000	2,240,000
Contained chromium[19]	do.	296,000	369,000	373,000	407,000	373,000
Average grade, dimensionless[20]		0.1629	0.1687 r	0.1683	0.1697 r	0.1667
Shipments, gross weight[21]	metric tons	1,670,000	1,720,000	1,790,000	1,880,000	1,730,000
Exports, gross weight	do.	249,000	273,000	327,000	323,000	371,000
Imports, gross weight	do.	761,000	752,000	639,000	811,000	770,000
Scrap, gross weight:						
Receipts	do.	832,000	1,020,000	1,060,000	987,000	731,000
Consumption	do.	1,220,000	1,380,000	1,430,000	1,410,000	1,060,000
Exports	do.	438,000	342,000	505,000	478,000	585,000
Imports	do.	42,300	81,000	89,200	146,000	111,000
Value of trade:						
Exports	thousands	$752,000	$742,000	$895,000	$1,030,000	$1,340,000
Imports	do.	$1,430,000	$1,350,000	$1,320,000	$2,230,000	$2,630,000
Scrap exports	do.	$270,000	$252,000	$382,000	$548,000	$670,000
Scrap imports	do.	$24,100	$49,400	$70,200	$160,000	$124,000
Net exports[17, 22]	do.	-$433,000	-$405,000	-$115,000	-$809,000	-$744,000

[e]Estimated. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Calculated assuming chromite ore to average 44% Cr_2O_3, which is 68.42% chromium.

[3]Calculated assuming chromium content of ferrochromium to average 57% chromium.

[4]Calculated assuming chromium content of stainless steel to average 17% chromium.

[5]2001 stocks were estimated based on the previous accounting system and reported sales. Stocks after 2001 are those reported by the National Defense Stockpile.

[6]Includes consumer stocks of chromium ferroalloys and metal and other chromium-containing materials.

[7]Includes chromium ferroalloys and metal and other chromium materials in the United States.

[8]Chromium ferroalloy, chromite ore, and other chromium-containing materials excluding chromium metal.

[9]Chromium ferroalloy and metal producer stocks of chromium ferroalloys and metal.

[10]Chemical, chromium ferroalloy and metal, and refractory producer stocks of chromite ore.

[11]Consumer stocks of chromium ferroalloys, chromite ore, and other chromium-containing materials excluding chromium metal.

[12]Time-weighted average U.S. price of imported high-carbon chromium that contains 50% to 55% chromium as reported in Platts Metals Week.

[13]Time-weighted average U.S. price of electrolytic chromium metal as reported in American Metal Market.

[14]Time-weighted average U.S. price of domestically produced electrolytic chromium metal as reported by Ryan's Notes.

[15]Time-weighted average U.S. price of imported aluminothermic chromium metal as reported by Ryan's Notes.

[16]Includes chromite ore and chromium ferroalloys, metal, and chemicals.

[17]Negative data indicate that imports are greater than exports.

[18]Source: American Iron and Steel Institute annual report of stainless and heat-resisting raw steel production and shipments.

[19]Estimated mass-weighted average of the mean chromium content of stainless steel production by grade. Uncertainty is approximatly ± 0.01 owing to the range of chromium chemical specification limits by stainless steel grade.

[20]Ratio of estimated mass-weighted average chromium content of stainless steel production by grade to production. Expressed as a fraction. Source: American Iron and Steel Institute quarterly reports of stainless and heat-resisting raw steel production by grade.

[21]Source: American Iron and Steel Institute annual report of stainless and heat-resisting raw steel shipments.

[22]Includes stainless steel and stainless steel scrap.

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TABLE 2

U.S. REPORTED CONSUMPTION AND STOCKS OF CHROMIUM PRODUCTS[1]

(Metric tons)

	2004		2005		Change[2]	
	Gross weight	Chromium content	Gross weight	Chromium content	Quantity	Percentage
Consumption by end use:						
Alloy uses:						
Iron alloys:						
Steel:						
Carbon steel	6,510	3,920	6,460	3,870	-51	-1
High-strength low-alloy steel	7,970	4,410	9,370	5,000	1,400	18
Stainless and heat-resisting steel	375,000	219,000	355,000	205,000	-19,500	-5
Full alloy steel	20,300	12,200	20,900	12,000	652	3
Tool steel	5,920	3,580	5,360	3,250	-560	-9
Superalloys	14,000	10,700	16,200	12,600	2,140	15
Other alloys[3]	21,700	12,400	21,700	12,600	36	--
Other uses not reported above	3,320 r	2,060 r	3,400	2,240	73	2
Total	454,000	268,000	439,000	257,000	-15,900	-3
Consumption by material:						
Low-carbon ferrochromium	37,100 r	25,200 r	36,200	24,500	-926	-2
High-carbon ferrochromium	372,000	222,000	354,000	209,000	-18,000	-5
Ferrochromium silicon	35,700	13,800	35,700	13,900	24	--
Chromium metal	5,690	5,690	7,280	7,270	1,580	28
Chromite ore	2,670	840	4,010	1,280	1,340	50
Chromium-aluminum alloy	617	420	549	380	-68	-11
Other chromium materials	507	295	659	267	152	30
Total	454,000	268,000	439,000	257,000	-15,900	-3
Consumer stocks:						
Low-carbon ferrochromium	2,120 r	1,440 r	2,170	1,470	47	2
High-carbon ferrochromium	9,560	5,690	10,700	6,300	1,100	12
Ferrochromium silicon	1,190	461	1,170	456	-19	-2
Chromium metal	182	182	228	228	46	25
Chromite ore	78	25	110	35	32	41
Chromium-aluminum alloy	89	61	120	83	31	35
Other chromium materials	64	37	75	31	11	17
Total	13,300	7,900 r	14,500	8,600	1,250	9
National Defense Stockpile stocks:[4]						
Chromite ore:[5]						
Chemical[6]	46,300	13,300	3,590	1,030	-42,800	-92
Refractory[7]	88,300	21,100	69,800	16,700	-18,500	-21
Chromium ferroalloys:[8]						
High-carbon ferrochromium[9]	398,000	284,000	319,000	228,000	-78,500	-20
Low-carbon ferrochromium[9]	197,000	141,000	173,000	123,000	-24,900	-13
Chromium metal[10]	6,670	6,670	6,190	6,190	-479	-7

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Change based on gross weight quantity of current year compared with that of previous year.

[3]Includes cast irons, welding and alloy hard-facing rods and materials, wear- and corrosion-resistant alloys, and aluminum, copper, magnetic, nickel, and other alloys.

[4]The source for stockpile materials is the Defense Logistics Agency, Defense National Stockpile Center.

[5]Metallurgical grade chromite ore was used up in 2002.

[6]Chromium content estimated using 28.6% chromium.

[7]Chromium content estimated using 23.9% chromium.

[8]Ferrochromium silicon was used up in 2002.

[9]Chromium content estimated using 71.4% chromium.

[10]Chromium content estimated using 100% chromium.

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TABLE 3

VALUE OF IMPORTS AND U.S. PRICE QUOTATIONS FOR CHROMIUM MATERIALS[1]

Material		2004 Contained chromium	2004 Gross weight	2005 Contained chromium	2005 Gross weight
Value:[2, 3]					
Chromite ore:					
Not more than 40% chromic oxide	dollars per metric ton	(4)	(4)	2,270	475
More than 40% but less than 46% chromic oxide	do.	776	239	257	81
46% or more chromic oxide	do.	349	113	476	153
Average	do.	354	114	437	140
Ferrochromium:					
Not more than 3% carbon:					
Not more than 0.5% carbon	do.	2,130	1,430	2,340	1,590
More than 0.5% but not more than 3% carbon	do.	2,150	1,440	1,890	1,230
Average (less than 0.5% but not more than 3%)	do.	2,140	1,430	2,310	1,560
More than 3% but not more than 4% carbon	do.	1,160	604	(5)	(5)
More than 4% carbon	do.	1,230	690	1,310	762
Average (all grades)	do.	1,320	754	1,430	846
Chromium metal	do.	XX	5,820	XX	8,010
Price:[6]					
High-carbon ferrochromium:[7]					
50% to 55% chromium	cents per pound	68.95	XX	68.40	XX
60% to 65% chromium	do.	68.55	XX	67.32	XX
Low-carbon ferrochromium:[7]					
0.05% carbon	do.	117	XX	118	XX
0.10% carbon	do.	103	XX	104	XX
0.15% carbon	do.	95	XX	100	XX
Chromium metal:					
Domestic, electrolytic[8]	do.	XX	450	XX	450
Imported:					
Aluminothermic[8]	do.	XX	227	XX	272
Aluminothermic[9]	do.	XX	185	XX	NA

NA Not available. XX Not applicable.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Mass-weighted average based on customs value and weight of imported material.

[3]Reported by the U.S. Census Bureau.

[4]No imports of not more than 40% chromite ore were reported in 2004.

[5]No imports of more that 3% but not more than 4% carbon ferrochromium were reported in 2005.

[6]Time-weighted average based on prices reported by material in trade journals.

[7]Source: Platts Metals Week.

[8]Source: Ryan's Notes.

[9]Source: American Metal Market.

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TABLE 4

U.S. EXPORTS OF CHROMIUM MATERIALS, BY TYPE[1]

HTS[2] code	Type	2004 Quantity (kilograms)	2004 Value (thousands)	2005 Quantity (kilograms)	2005 Value (thousands)	Principal destinations in 2005
2610.00.0000	Chromite ore and concentrate, gross weight	43,100,000	$10,400	42,600,000	$9,940	China (66.2%); Canada (17.1%); Mexico (10.8%); Sweden (5.4%).
	Metal and alloys, gross weight:					
8112.21.0000	Unwrought chromium powders	261,000	3,250	169,000	2,940	Canada (35.3%); Japan (23.4%); Germany (16.2%); Belgium (5.4%); Singapore (5.2%); Mexico (4.9%); Malaysia (3.1%); China (1.6%); Italy (1.2%).
8112.22.0000	Chromium metal waste and scrap	125,000	3,320	227,000	4,260	Japan (75.5%); Belgium (11.4%); Germany (5.0%); Netherlands (3.6%); Austria (2.7%); Singapore (1.8%).
8112.29.0000	Chromium metal other than unwrought powders and waste and scrap	545,000	11,000	628,000	9,680	Japan (64.5%); Singapore (6.4%); Chile (5.3%); Saudi Arabia (4.8%); Peru (3.8%); Mexico (3.2%); South Africa (2.4%); Brazil (2.1%); Taiwan (2.0%); Canada (1.3%).
	Total chromium metal	931,000	17,600	1,020,000	16,900	
	Chromium ferroalloys:					
7202.41.0000	High-carbon ferrochromium:[3]					Netherlands (81.8%); Canada (11.1%); Mexico (5.3%); Brazil (1.3%).
	Gross weight	6,580,000	7,570	30,700,000	31,100	
	Contained weight	4,060,000	XX	20,100,000	XX	
7202.49.0000	Low-carbon ferrochromium:[4]					Netherlands (66.1%); Mexico (22.8%); Canada (7.5%).
	Gross weight	1,410,000	3,090	5,460,000	7,560	
	Contained weight	852,000	XX	3,540,000	XX	
7202.50.0000	Ferrochromium-silicon:					Canada (62.7%); Mexico (23.9%); Malaysia (13.1%).
	Gross weight	1,150,000	1,300	147,000	186	
	Contained weight	403,000	XX	51,400	XX	
	Total ferroalloys:					
	Gross weight	9,140,000	12,000	36,300,000	38,900	
	Contained weight	5,320,000	XX	23,700,000	XX	
	Chemicals, gross weight:					
	Chromium oxides:					
2819.10.0000	Chromium trioxide	10,700,000	14,300	9,000,000	11,000	China (25.8%); Brazil (16.8%); India (14.0%); Chile (11.1%); Republic of Korea (8.7%); Taiwan (4.9%); Japan (2.6%); Mexico (2.6%); Indonesia (2.2%); Colombia (1.9%); Thailand (1.4%); Hong Kong (1.7%); Canada (1.0%).
2819.90.0000	Other	2,130,000	7,840	1,660,000	7,300	Canada (28.3%); Brazil (14.8%); United Kingdom (11.3%); Taiwan (6.0%); Mexico (5.4%); Hong Kong (3.6%); Chile (3.5%); Venezuela (3.4%); Japan (3.2%); France (3.1%); India (2.4%); Thailand (2.3%); Germany (2.0%); Australia (1.5%); Singapore (1.3%); Malaysia (1.2%); South Africa (1.2%).
2833.23.0000	Chromium sulfates	38,500	417	78,900	376	Hong Kong (26.5%); Colombia (24.7%); Canada (19.7%); Republic of Korea (9.6%); Germany (6.5%); Taiwan (5.6%); Singapore (5.4%).

See footnotes at end of table.

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TABLE 4—Continued
U.S. EXPORTS OF CHROMIUM MATERIALS, BY TYPE[1]

HTS[2] code	Type	2004 Quantity (kilograms)	2004 Value (thousands)	2005 Quantity (kilograms)	2005 Value (thousands)	Principal destinations in 2005
	Chemicals, gross weight—Continued:					
	Salts of oxometallic or peroxometallic acids:					
2841.20.0000	Zinc and lead chromate	74,500	$236	65,500	$269	Canada (67.0%); Mexico (9.3%); Trinidad and Tobago (7.5%); Jamaica (4.1%); Barbados (3.5%); El Salvador (2.1%); Guatamala (1.5%); Nicaragua (1.5%); New Zealand (1.4%).
2841.30.0000	Sodium dichromate	21,200,000	12,300	37,200,000	25,000	Japan (56.7%); Mexico (22.9%); Canada (12.6%); Peru (2.1%); Germany (1.8%); China (1.4%); Taiwan (1.0%).
2841.50.0000	Other chromates, dichromates, and peroxochromates:					
2841.50.1000	Potassium dichromate	23,400	63	127,000	285	Canada (61.4%); Brazil (30.4%); Australia (7.1%).
2841.50.9000	Other	514,000	1,740	529,000	1,650	France (24.9%); Republic of Korea (16.3%); China (14.3%); Mexico (12.4%); Canada (10.4%); Malaysia (6.2%); Hong Kong (5.6%); Portugal (2.5%); India (1.8%); Saudi Arabia (1.7%); Taiwan (1.0%).
3206.20.0000	Pigments and preparations, gross weight	671,000	3,780	767,000	4,090	Canada (42.9%); Mexico (17.9%); Colombia (5.2%); Honduras (4.5%); Philippines (3.5%); Australia (2.9%); France (2.6%); Switzerland (2.3%); Taiwan (2.3%); Thailand (1.8%); Republic of Korea (1.7%); Venezuela (1.5%); Italy (1.3%); United Kingdom (1.1%); India (1.0%).

XX Not applicable.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States of America.

[3]More than 4% carbon.

[4]Not more than 4% carbon.

Source: U.S. Census Bureau.

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TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF FERROCHROMIUM, BY COUNTRY[1]

Country	Not more than 0.5% carbon (HTS[2] code 7202.49.5090)			More than 0.5% carbon, but not more than 3% carbon (HTS[2] code 7202.49.5010)			More than 3% carbon, but not more than 4% carbon (HTS[2] code 7202.49.1000)			More than 4% carbon (HTS[2] code 7202.41.0000)			Total all grades		
	Gross weight (metric tons)	Cr content (metric tons)	Value (thousands)	Gross weight (metric tons)	Cr content (metric tons)	Value (thousands)	Gross weight (metric tons)	Cr content (metric tons)	Value (thousands)	Gross weight (metric tons)	Cr content (metric tons)	Value (thousands)	Gross weight (metric tons)	Cr content (metric tons)	Value (thousands)
2004:															
China	194 r	126 r	$341 r	20	9	$42	--	--	--	--	--	--	214 r	135 r	$383 r
Germany	4,930	3,490	8,930	63	44	72	--	--	--	--	--	--	4,990	3,530	9,010
India	--	--	--	--	--	--	--	--	--	12,900	8,110	$10,400	12,900	8,110	10,400
Japan	2,060	1,450	4,780	--	--	--	--	--	--	--	--	--	2,060	1,450	4,780
Kazakhstan	1,170	788	1,660	2,020	1,400	3,520	--	--	--	87,000	60,200	84,200	90,200	62,400	89,300
Russia	17,900	12,400	24,700	2,100	1,450	2,830	--	--	--	9,170	6,220	7,560	29,200	20,100	35,100
South Africa	5,010	2,730	4,270	1,520	927	1,780	30	16	$18	244,000	122,000	145,000	251,000	126,000	151,000
Turkey	135	92	262	--	--	--	--	--	--	--	--	--	135	92	262
Zimbabwe	--	--	--	--	--	--	--	--	--	44,600	26,500	28,200	44,600	26,500	28,200
Total	31,400	21,100	44,900	5,720	3,830	8,250	30	16	18	398,000	223,000	275,000	435,000	248,000	328,000
2005:															
Australia	--	--	--	--	--	--	--	--	--	13	9	11	13	9	11
China	94	66	212	--	--	--	--	--	--	13	8	11	107	74	223
France	4	3	8	--	--	--	--	--	--	--	--	--	4	3	8
Germany	5,810	4,070	11,700	--	--	--	--	--	--	--	--	--	5,810	4,070	11,700
India	--	--	--	20	13	17	--	--	--	20	12	16	40	24	33
Japan	2,870	2,010	8,130	--	--	--	--	--	--	--	--	--	2,870	2,010	8,130
Kazakhstan	3,910	2,680	5,880	870	601	1,370	--	--	--	115,000	79,400	112,000	119,000	82,700	119,000
Mexico	41	34	72	--	--	--	--	--	--	--	--	--	41	34	72
Russia	27,300	18,800	39,600	1,830	1,240	2,030	--	--	--	35,100	23,000	28,900	64,300	43,000	70,500
South Africa	2,950	1,630	2,760	810	446	905	--	--	--	187,000	93,600	115,000	190,000	95,600	119,000
Sweden	38	27	136	--	--	--	--	--	--	260	173	293	298	201	428
Turkey	5	3	12	--	--	--	--	--	--	--	--	--	5	3	12
Zimbabwe	--	--	--	--	--	--	--	--	--	61,200	36,200	47,500	61,200	36,200	47,500
Total	43,000	29,300	68,500	3,530	2,300	4,330	--	--	--	398,000	232,000	303,000	444,000	264,000	376,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States of America.

Source: U.S. Census Bureau.

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TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF CHROMIUM MATERIALS, BY TYPE[1]

HTS[2] code	Type	2004 Quantity (kilograms)	2004 Value[3] (thousands)	2005 Quantity (kilograms)	2005 Value[3] (thousands)	Principal sources in 2005
	Chromite ore:					
2610.00.0020	Not more than 40% Cr_2O_3:					Canada (100%).
	Gross weight	--	--	36,000	$17	
	Cr_2O_3 content	--	XX	11,000	XX	
2610.00.0040	More than 40%, but less than 46% Cr_2O_3:					South Africa (100%).
	Gross weight	1,690,000	$404	29,700,000	2,400	
	Cr_2O_3 content	761,000	XX	13,700,000	XX	
2610.00.0060	46% or more Cr_2O_3:					South Africa (100%).
	Gross weight	151,000,000	17,100	135,000,000	20,700	
	Cr_2O_3 content	71,600,000 r	XX	63,600,000	XX	
	Total:					
	Gross weight	153,000,000	17,500	165,000,000	23,100	
	Cr_2O_3 content	72,400,000 r	XX	77,300,000	XX	
	Metals and alloys:					
7202.50.0000	Ferrochromium-silicon:					Kazakhstan (77.0%); Russia (23.0%).
	Gross weight	30,600,000	31,500	33,700,000	31,600	
	Cr_2O_3 content	12,500,000	XX	14,100,000	XX	
	Chromium metal, gross weight:					
8112.21.1000	Unwrought chromium powders	1,350,000	9,070	1,050,000	15,000	Russia (33.0%); China (31.6%); Japan (28.5%); Spain (3.6%); Germany (1.8%); France (1.2%).
8112.22.0000	Waste and scrap	74,000	491	57,500	564	Singapore (63.9%); Japan (25.4%); Germany (9.7%); United Kingdom (0.9%).
8112.29.0000	Other than waste and scrap	8,200,000	46,500	9,850,000	72,100	Russia (29.1%); China (26.9%); France (26.2%); United Kingdom (17.0%).
	Total	9,630,000	56,000	11,000,000	87,700	
	Chemicals, gross weight:					
	Chromium oxides and hydroxides:					
2819.10.0000	Chromium trioxide	7,000,000	10,500	11,400,000	21,600	Turkey (41.9%); Kazakhstan (24.7%); United Kingdom (23.1%); China (5.5%); South Africa (3.8%).
2819.90.0000	Other	2,960,000	8,400	3,200,000	11,000	China (42.8%); Japan (22.9%); Germany (16.5%): United Kingdom (6.8%); Colombia (2.6%); Spain (2.3%); Poland (1.8%); France (1.4%); Russia (1.2%); Taiwan (0.8%); Hong Kong (0.5%).
2833.23.0000	Sulfates of chromium	111,000	161	288,000	438	United Kingdom (92.0%); Kazakhstan (7.0%); India (1.0%).
	Salts of oxometallic or peroxometallic acids:					
2841.20.0000	Chromates of lead and zinc	710,000	1,630	614,000	1,440	Republic of Korea (70.6%); Austria (17.7%); Colombia (6.7%); Japan (3.3%); China (1.5%).
2841.30.0000	Sodium dichromate	494,000	380	8,980,000	5,360	United Kingdom (90.1%); South Africa (7.6%); China (1.2%); Canada (0.6%).
2841.50.0000	Other chromates and dichromates; peroxochromates:					
2841.50.1000	Potassium dichromate	105,000	187	84,000	156	Kazakhstan (91.9%); India (6.7%); Japan (1.0%).
2841.50.9000	Other	570,000	1,240	212,000	507	Austria (97.0%); France (1.4%); India (1.0%).

See footnotes at end of table.

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TABLE 6—Continued

U.S. IMPORTS FOR CONSUMPTION OF CHROMIUM MATERIALS, BY TYPE[1]

HTS[2] code	Type	2004 Quantity (kilograms)	2004 Value[3] (thousands)	2005 Quantity (kilograms)	2005 Value[3] (thousands)	Principal sources in 2005
	Chemicals, gross weight—Continued:					
2849.90.2000	Chromium carbide	138,000	$1,630	131,000	$2,150	Japan (33.1%); Canada (18.8%); Germany (16.7%); United Kingdom (15.1%); Austria (10.6%); China (5.6%).
	Pigments and preparations based on chromium, gross weight:					
3206.20.0010	Chrome yellow	5,300,000	12,400	4,770,000	13,600	Canada (40.1%); Republic of Korea (32.0%); Mexico (17.3%); China (5.2%); Hungary (2.2%); Colombia (1.3%); Japan (1.2%).
3206.20.0020	Molybdenum orange	1,030,000	4,760	983,000	4,780	Canada (71.3%); Mexico (15.0%); France (10.3%); Colombia (0.9%); Germany (0.9%); India (0.6%).
3206.20.0030	Zinc yellow	15,600	29	11,000	28	Mexico (96.4%); Canada (3.6%).
3206.20.0050	Other	1,200,000	2,980	1,750,000	3,700	France (45.2%); China (20.0%); Canada (16.1%); Russia (7.9%); Belgium (5.1%); Poland (2.2%); Germany (1.8%); India (0.8%).

[r]Revised. XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States of America code.

[3]Customs import value generally represents a value in the foreign country and therefore excludes U.S. import duties, freight, insurance, and other charges incurred in bringing the merchandise into the United States.

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TABLE 7

WORLD PRODUCTION CAPACITY OF CHROMITE ORE, FERROCHROMIUM, CHROMIUM METAL, CHROMIUM CHEMICALS, AND STAINLESS STEEL, AND APPARENT CONSUMPTION IN 2005[1]

(Thousand metric tons of contained chromium)

	Production capacity					
Country	Ore	Ferrochromium	Metal	Chemicals	Stainless steel	Apparent consumption[2]
Afghanistan	2	--	--	--	--	--
Albania	48	24	--	--	--	28
Argentina	--	--	--	13	--	21
Australia	78	--	--	--	--	-52
Austria	--	--	--	--	8	100
Belgium	--	--	--	--	120	111
Brazil	197	113	--	--	96	180
Canada	--	--	--	--	--	24
China	69	468	6	70	595	1,070
Cuba	13	--	--	--	--	4
Czech Republic	--	--	--	--	2	--
Finland	174	138	--	--	221	164
France	--	--	7	--	112	97
Germany	--	18	1	--	298	261
Greece	1	--	--	--	--	(3)
India	980	318	(3)	4	306	530
Indonesia	--	--	--	--	--	-31
Iran	67	12	--	2	--	(3)
Italy	--	--	--	--	272	235
Japan	1	8	1	17	714	563
Kazakhstan	1,080	637	2	37	--	395
Korea, Republic of	--	--	--	--	425	266
Madagascar	42	--	--	--	--	35
Oman	9	--	--	--	--	-13
Pakistan	45	--	--	3	--	-6
Philippines	21	--	--	--	--	-4
Poland	--	--	--	--	--	3
Russia	232	333	16	31	17	313
Slovakia	--	1	--	--	--	(3)
Slovenia	--	--	--	--	13	-1
South Africa	2,300	1,540	--	23	122	616
Spain	--	--	--	--	204	107
Sudan	11	--	--	--	--	--
Sweden	--	81	--	--	119	77
Taiwan	--	--	--	--	272	212
Turkey	259	23	--	17	--	35
Ukraine	--	--	--	--	19	(3)
United Arab Emirates	2	--	--	--	--	(3)
United Kingdom	--	--	7	17	85	66
United States	--	20	3	38	425	266
Vietnam	59	--	--	--	--	--
Yugoslavia	--	--	--	--	91	--
Zimbabwe	247	165	--	--	--	127
Total	5,930	3,900	43	272	4,540	XX

XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Apparent consumption is chromite ore production plus chromite ore, ferrochromium, and chromium metal net imports. Net imports are imports minus exports. Based on data reported by the International Chromium Development Association. A negative apparent consumption indicates that exports are greater than production plus imports.

[3]Less than ½ unit.

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TABLE 8

CHROMITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, gross weight)

Country[3]	2001	2002	2003	2004	2005
Afghanistan[4]	5,682	6,136	6,364	6,591 r	-- e
Albania[5]	129,700 r	72,600 r	98,000 r	54,430 r	66,270
Australia	11,800	132,665	138,826	265,987	241,865
Brazil[6]	409,049	283,991	404,477	593,476 r	676,643
Burma[e]	307	318	341	-- e	-- e
China[e]	182,000	180,000	200,000	200,000	200,000
Cuba	49,500 r	20,400 r	33,300 r	40,300 r	40,000 e
Finland	575,126	566,090	549,040	579,780	598,000 e
India	1,677,924	2,698,577	2,210,000	2,948,944	3,255,162
Iran	145,170 r	512,640 r	97,238 r	138,775 r	223,563
Kazakhstan	2,045,700	2,369,400	2,927,500	3,267,000	3,579,000
Madagascar	23,637	11,000	45,040	77,386	140,847
Oman	30,150 r	27,444	13,000	18,585	18,386
Pakistan	64,000	62,005	98,235	129,500 r	148,432
Philippines	26,932	23,703	12,967 r	70,001 r	60,424
Russia	69,926	74,300	116,455	320,200	772,000
South Africa	5,502,010	6,435,746	7,405,391	7,677,000 r	7,502,762 p
Sudan	20,500	14,000	37,000	26,000	21,654
Turkey	389,759	313,637	229,294 r	506,421 r	858,729
United Arab Emirates[e]	10,000	--	--	7,089 [7]	--
Vietnam[e]	70,300	80,000	120,000	150,000	85,000
Zimbabwe	780,150	749,339	637,099	668,391	819,903
Total	12,200,000 r	14,600,000 r	15,400,000 r	17,700,000 r	19,300,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 30, 2006.

[3]Figures for all countries represent marketable output unless otherwise noted.

[4]Gross weight estimated assuming an average grade of 44% chromic oxide (Cr_2O_3).

[5]Direct shipping plus concentrate production.

[6]Average chromic oxide (Cr_2O_3) content was as follows: 2001–43.5% (revised); 2002–40.1%; 2003–41.1% (revised); 2004–42.6% (revised); and 2005–42.6%.

[7]Reported figure.

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TABLE 9

FERROCHROMIUM: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, gross weight)

Country	2001	2002	2003	2004	2005
Albania	11,900	22,100	37,800	47,700 r	35,780
Brazil[3]	110,468	164,140 r	204,339	216,277	185,533
China e	310,000	330,000	500,000	640,000 r	750,000
Croatia	361	--	--	--	--
Finland	236,710	248,181	250,490	264,492	234,881
Germany	19,308	20,018	18,318	24,857	22,672
India[4]	267,395	311,927	468,677	527,100	611,373
Iran e	8,430 [5]	8,000 r	10,000 r	7,750 r, [5]	8,000
Japan[3]	111,167	91,937	19,427	13,472 r	12,367
Kazakhstan	761,900	835,800	993,000	1,080,993 r	1,156,168
Norway	82,600	61,100	--	--	--
Russia	210,600	210,000	357,000	454,000 e	578,000
Slovakia	5,968	5,695	1,924	1,784	867
South Africa[6]	2,141,000	2,351,122	2,813,000	2,965,000 r	2,581,578
Sweden	109,198	118,823	110,529	128,191	127,451
Turkey	50,735	11,200	35,393	28,701 r	26,043
United States[7]	W	W	W	W	W
Zimbabwe	243,584	258,164	245,200	193,077	235,000 e
Total	4,680,000	5,050,000 r	6,070,000	6,590,000 r	6,570,000

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table inculdes data available through June 30, 2006.

[3]Includes high- and low-carbon ferrochromium.

[4]Includes ferrochrome and charge chrome.

[5]Reported figure.

[6]Includes high- and low-carbon ferrochromium and ferrochromiumsilicon.

[7]Includes chromium metal, high- and low-carbon ferrochromium, ferrochromiumsilicon, and other chromium materials.

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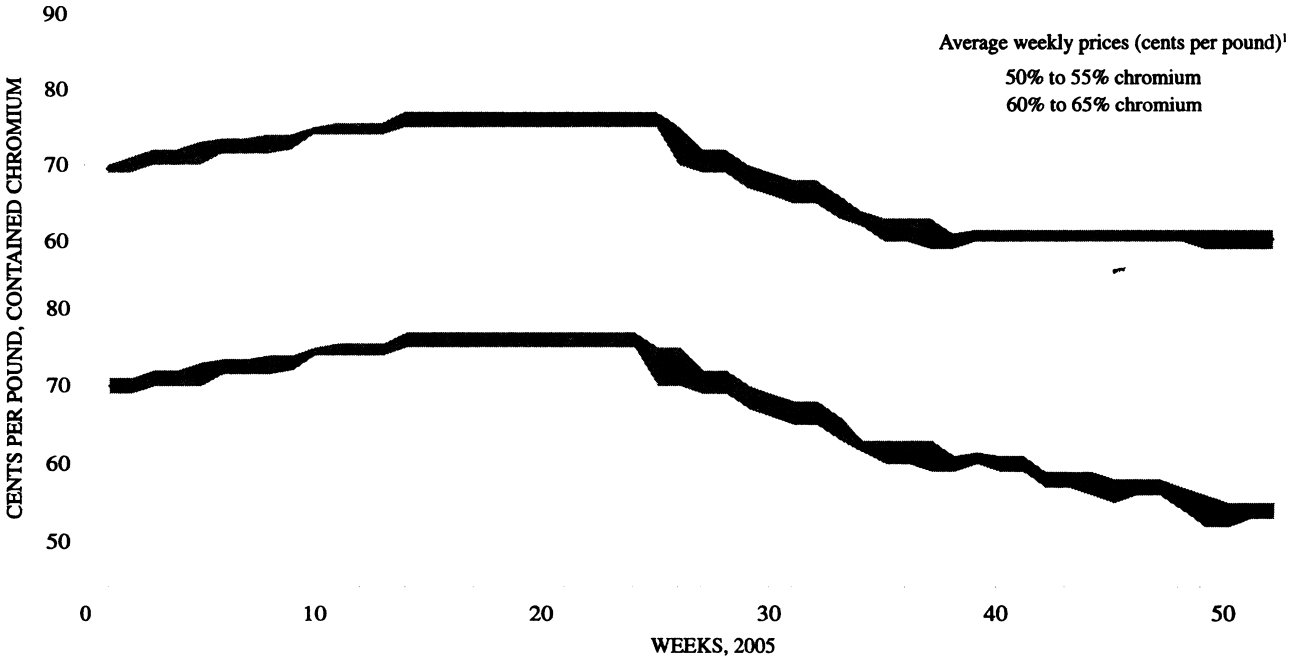
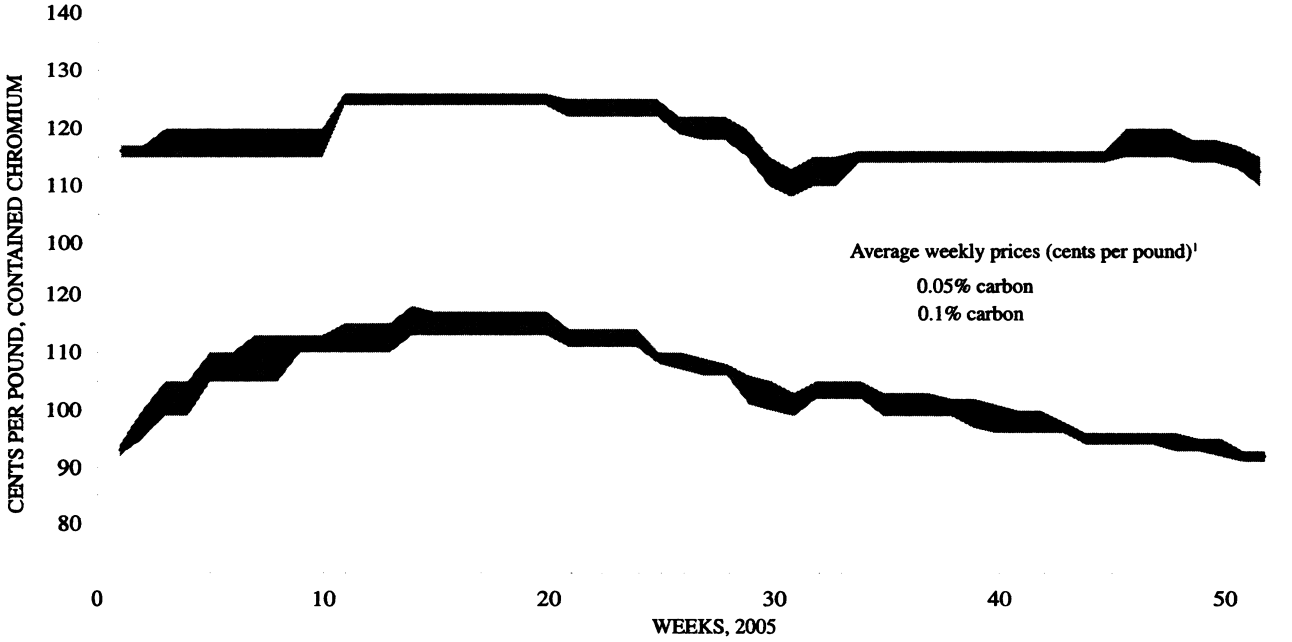
FIGURE 1
U.S. IMPORTED HIGH-CARBON FERROCHROMIUM IN 2005



[1]Average weekly price shown against price range background.

Source: Platts Metals Week.

FIGURE 2
U.S. IMPORTED LOW-CARBON FERROCHROMIUM IN 2005



[1]Average weekly price shown against price range background.

Source: Platts Metals Week.

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CLAY AND SHALE

By Robert L. Virta

Domestic survey data and tables were prepared by Maria Arguelles, Virginia C. Harper, and Hoa P. Phamdang, statistical assistants, and the world production tables were prepared by Linder Roberts, international data coordinator.

The amount of clay sold or used by domestic producers in 2005 was 41.7 million metric tons (Mt) valued at $1.65 billion (excluding the tonnage and value of attapulgite-type fuller's earth) compared with 41.2 Mt valued at $1.68 billion in 2004 (table 1). Common clay and shale accounted for 59% of the tonnage, and kaolin accounted for 52% of the value (tables 1, 5, and 8). Imports of clays were 301,000 metric tons (t) valued at $59.4 million. Exports were 5.62 Mt valued at $929 million (table 1).

Major domestic and exports markets, in decreasing order by tonnage, for ball clay were floor and wall tile (40%), sanitaryware (25%), and pottery and miscellaneous ceramics (12%); for bentonite, absorbents (26%), foundry sand bond (23%), drilling mud (22%), and iron ore pelletizing (13%); for common clay and shale, brick (61%), lightweight aggregate (16%), and portland cement (15%); for fire clay, heavy-clay products (54%) and refractory products (46%); for fuller's earth, absorbents (86%); and for kaolin, paper coating and filling (61%).

Production

About 220 companies mined clay and shale in the United States in 2005. The 20 leading companies, many with multiple operations, accounted for 49% of the tonnage and 78% of the value for all types of clay produced and sold or used. Clay production was reported in all States except Alaska, Delaware, Hawaii, Idaho, New Hampshire, Rhode Island, Vermont, and Wisconsin (table 2). Companies not participating in the U.S. Geological Survey (USGS) canvass of the clay and shale industry probably mined clay for construction uses in States for which no production was reported.

The 10 leading producer States were, in decreasing order of tonnage, Georgia, Wyoming, Texas, Alabama, North Carolina, Missouri, South Carolina, Ohio, Arkansas, and Mississippi. The 10 leading producer companies were, in alphabetical order, Acme Brick Co. (common clay and shale); American Colloid Co. (bentonite); Engelhard Corp. (bentonite, fuller's earth, and kaolin); General Shale Products Corp. (common clay and shale); Glen Gery Corp. (common clay and shale); Imerys (ball clay and kaolin); J.M. Huber Corp. (kaolin); Oil-Dri Corp. (fuller's earth); Thiele Kaolin Co. (kaolin); and Unimin Corp. (ball clay and kaolin).

Most clay mining in the United States was by open pit methods; less than 1% of U.S. clay output was from underground mines. All underground production was in Ohio, where the clays are mainly underclays associated with coal.

Domestic production data for clays were developed by the USGS from a voluntary survey of U.S. operations. Responses to the survey and company production data available from other sources accounted for approximately 65% of the total clay and shale tonnage sold or used quantity listed in table 1. Most nonrespondents were producers of common clay and shale. Production data for the nonrespondents were estimated from reported prior year production levels adjusted by trends in the industry and other guidelines.

Ball Clay.—In 2005, 4 companies mined ball clay in 4 States. Production of domestic ball clay was estimated to be 1.21 Mt valued at $52.9 million in 2005 versus 1.22 Mt valued at $54.1 million in 2004 (table 3). The production tonnage was essentially unchanged from that of 2004 although the value declined about 2% as more lesser-valued airfloat product and less slurried product were sold or used in 2005 than in 2004. Operations in Tennessee supplied 61% of the Nation's output, followed by, in descending order of tonnage, Texas, Mississippi, and Kentucky. One producer reported a small amount of production in Indiana, but this probably was fire clay rather than ball clay.

Bentonite.—In 2005, 20 companies produced bentonite in 11 States. About 4.71 Mt valued at $215 million of bentonite was sold or used in 2005 compared with 4.55 Mt valued at $206 million in 2004 (table 4). Production of nonswelling bentonite decreased to 300,000 t valued at $14.4 million in 2005 versus 320,000 t valued at $14.2 million in 2004. Mississippi led in the production of nonswelling bentonite, followed by, in descending order of tonnage, Alabama, Arizona, Nevada, California, and Colorado.

Production of swelling bentonite increased to 4.41 Mt valued at $201 million in 2005, an increase from 4.23 Mt valued at $192 million in 2004. The increase was distributed among many producers. Wyoming led in the production of swelling bentonite, followed by Montana, Utah, Texas, California, Oregon, and Nevada.

Süd-Chemie AG sold its rheological additives line to Rockwood Holdings, Inc. The sale includes bentonite, organoclay, and activated clay products used in coatings, ink, paint, and personal care products as well as production facilities in Germany and Kentucky. Rockwood Holdings will sell these products through its subsidiary, Southern Clay Products, Inc. (Süd-Chemie AG, 2005; Rockwood Holdings, Inc., 2006).

After BPM Minerals LLC increased its capacity by 20% for granular bentonite products at its Lovell, WY, operation in 2004, BPM completed a similar expansion at its Colony, WY, plant. BPM indicated that strong global growth in animal feed supplements and beverage clarification, and U.S. growth in environmental lining and consumer sorbent markets prompted the expansion (BPM Minerals LLC, 2005§[1]).

[1]References that include a section mark (§) are found in the Internet References Cited section.

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Common Clay and Shale.—In 2005, 155 companies produced common clay and shale in 41 States and Puerto Rico. In States not reporting production, common clay and shale probably was mined and sold for construction uses by companies not participating in the USGS canvass of the clay and shale industry.

Domestic sales or use of common clay and shale decreased to 24.5 Mt valued at $176 million in 2005 compared with 24.6 Mt valued at $173 million in 2004 (table 5). The increase in value probably will be viewed with caution because many producers do not sell their clay but use it to manufacture their heavy-clay products. Consequently, producers often have difficulty assigning a value to the clay used in their production of such products as clay brick, flower pots, flue linings, roofing tile, and sewer pipe. The major producing States were, in descending order of tonnage, Texas, Alabama, North Carolina, Georgia, Ohio, Arkansas, Kentucky, South Carolina, California, and Oklahoma.

Boral USA (a subsidiary of Boral Ltd.) announced plans to construct a $55 million brick plant in Terre Haute, IN. The plant will have a capacity of 120 million bricks per year and will serve customers in the Midwest (Boral USA, 2005).

Carolina Ceramics Brick Co. completed a $25 million expansion, doubling its brick manufacturing capacity to 80 million metric tons per year (Mt/yr) (Ceramic Industry, 2005).

Palmetto Brick Co. opened a $28 million manufacturing plant in Cheraw, SC. The plant will expand the company's production capacity to 150 million bricks per year from 100 million bricks per year (Palmetto Brick Co., 2005).

Fire Clay.—Fire clay producers were mostly refractory product manufacturers that used the clays in firebrick and various heavy-clay products. In 2005, five firms mined fire clay in three States. Fire clay sold or used by domestic producers increased to 353,000 t valued at $10.7 million versus 307,000 t valued at $8.51 million in 2004 (table 6). The increase was primarily the result of increased sales for the manufacture of heavy-clay products rather than refractory applications. Missouri was the leading producing State, followed by, in descending order of tonnage, Ohio and South Carolina.

Fuller's Earth.—In 2005, 15 companies produced fuller's earth (attapulgite and montmorillonite varieties) in 11 States. The fuller's earth deposits grade from attapulgite in Florida to montmorillonite further northward in Georgia. Only those clays with attapulgite as the major clay component are classified as attapulgite. These basically are the gellant-grade fuller's earths in Florida and the southernmost part of Georgia. Going northward into Georgia, the attapulgite content of the fuller's earth declines, and montmorillonite becomes the dominant clay present. This is classified under montmorillonite although it contains minor to trace amounts of attapulgite.

The attapulgite variety of fuller's earth was mined in the Florida Panhandle and southwestern Georgia. Attapulgite production increased in 2005 but data were concealed to avoid revealing company proprietary data. Production in 2004 was 237,000 t valued at $30.1 million (table 7). Georgia led in the production of attapulgite, followed by Florida.

Production of the montmorillonite variety of fuller's earth declined to 2.99 Mt valued at $302 million in 2005 compared with 3.02 Mt valued at $299 million in 2004 (table 7). Montmorillonite was produced, in decreasing order of tonnage, in Georgia, Missouri, Mississippi, Virginia, Illinois, California, Florida, Tennessee, Texas, and Kansas.

Sepiolite, although not a fuller's earth, was produced in Nevada. Sepiolite was included in the total for attapulgite to avoid disclosing company proprietary data.

Süd-Chemie Group sold its fuller's earth operation (Waverly Mineral Products, Co., Meigs, GA) to Mid-Florida Mining Industries, Inc. (MFM) of Florida. Production at the Georgia operation is about 70,000 metric tons per year (t/yr). About 80% is sold for oil and grease absorbent applications. The purchase of the Süd-Chemie operation allowed MFM to focus sales of fuller's earth from its Florida operation on pet litter applications (Industrial Minerals, 2005c).

Kaolin.—In 2005, 21 firms mined kaolin in 10 States. Domestic production was reported to be 7.8 Mt valued at $860 million compared with 7.76 Mt valued at $936 million in 2004 (table 8). One and possibly two producers appear to have undervalued their kaolin in 2005 on the USGS survey. When adjustments were made to the value data, production was valued at about $910 million. While kaolin production increased elsewhere, the combined total for the four leading producers of paper-grade kaolin in Georgia declined. The leading producer State was Georgia, followed by, in descending order of tonnage, South Carolina, Alabama, Arkansas, California, Texas, Nevada, Florida, North Carolina, and Tennessee.

Of the 7.8 Mt mined in 2005, 4.07 Mt was reported as water washed, 1.31 Mt was calcined, 1.01 Mt was delaminated, 1.27 Mt was airfloat, and 139,000 t was unprocessed (table 8). This compares with 3.87 Mt of water washed, 1.40 Mt of calcined, 1.24 Mt of delaminated, 1.15 Mt of airfloat, and 101,000 t of unprocessed in 2004. One producer appears to have reported delaminated kaolin as water-washed kaolin in 2005. Adjusting for this error gives a production of about 3.8 Mt water washed and 1.28 Mt delaminated, more in-line with that produced in 2004. There was a small decline in the U.S. production of refractory-grade (high-temperature) calcined kaolin. Of the calcined kaolin, 837,000 t was pigment-grade (low-temperature calcined kaolin). Companies in Georgia accounted for nearly all the pigment-grade calcined kaolin produced in 2005. A small amount also was produced in Texas. The remainder was refractory-grade (high-temperature calcined kaolin) (table 8).

Kaolin production in Georgia was reported to be 7.19 Mt valued at $825 million in 2005 compared with 6.78 Mt valued at $889 million in 2004. The 2005 value probably will be increased to about $875 million because of the undervaluing of some kaolin products. Approximately 3.97 Mt of Georgia kaolin production was reported as sold as water washed, 1.01 Mt was delaminated, 1.19 Mt was calcined (high- and low-temperature calcined kaolin), and 1.01 Mt was airfloat (see the preceding paragraph for comments on the reporting of delaminated and water-washed kaolin production data; table 9). This compares with 3.78 Mt water washed, 1.24 Mt delaminated, 906,000 t calcined, and 851,000 t airfloat in 2004. The change in airfloat kaolin production is attributable mainly to one company, which reported incorrectly in 2003 and 2004. Airfloat kaolin production probably was nearer 1.0 Mt in 2004. Calcined kaolin production did not increase as significantly as indicated in table 9. In the past, one

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producer reported the bulk of prior year refractory-grade calcined kaolin production at its Alabama, rather than Georgia, operation. Giving consideration to these two problems, estimated production in Georgia in 2004 probably was closer to 7 or 7.1 Mt than to 6.78 Mt. Production in South Carolina was 287,000 t valued at $17.7 million in 2005 compared with 296,000 t valued at $19.6 million in 2004 (table 10).

J.M. Huber Corp. was negotiating to acquire 600,000 t of crude kaolin from Sparta Kaolin Corp. (a subsidiary of Kaoclay Resources Inc.). Details of the negotiations were not available (Kaoclay Resources Inc., 2005).

Imerys, a French investment group, announced further reductions in the Dry Branch, GA, processing plant. One calciner will be shut down and plant capacity will be reduced by 45,000 t/yr. Some of the paper- and specialty-grade kaolin products will be discontinued (Industrial Minerals, 2005b). Imerys also concentrated its production of kaolin for fiberglass markets at its Sandersville, GA, plant (Imerys, 2006, p. 12).

Oglebay Norton Co. completed the sale of its subsidiary (Oglebay Norton Specialty Minerals, Inc.) to Zemex Corp. The $15 million purchase included all the Kings Mountain, NC, operation (Oglebay Norton Co., 2005).

i-minerals inc., continued its testing of kaolin from the Helmer-Bovill property in Idaho. The crude ore is composed primarily of quartz with halloysite, kaolinite clays, muscovite, and microcline as accessory minerals. Products with 80% of particles less than 2 micrometers (μm) in diameter are composed of halloysite and kaolinite; those with 90% less than 2 μm are primarily kaolinite with minor halloysite and quartz (i-minerals inc., 2005).

Consumption

Ball Clay.—The principal domestic ball clay markets were, in decreasing order, floor and wall tile, sanitaryware, and miscellaneous ceramics (table 3). Sales and use, including exports, were 1.21 Mt, essentially unchanged from those of 2004.

Bentonite.—Domestic sales and use were estimated to be 4.31 Mt and total sales (domestic and export) were 4.71 Mt in 2005 compared with domestic sales of 4.09 Mt and total sales of 4.55 Mt in 2004 (table 4). Major domestic markets for bentonite were, in decreasing order by tonnage, pet waste absorbent, drilling mud, foundry sand, and iron ore pelletizing. Total sales (domestic and exports) of bentonite were approximately 1.1 Mt for foundry sand bond (more than 85% was swelling bentonite), 1.26 Mt for pet waste absorbent (all swelling bentonite), 1.02 Mt for drilling mud (all swelling bentonite), and 595,000 t for pelletizing iron ore (all swelling bentonite).

Data for other bentonite markets were concealed to avoid disclosing company proprietary data. However, swelling bentonite accounted for more than 90% of the bentonite sold for absorbents, animal feed, civil engineering, drilling mud, miscellaneous chemical manufacture applications, medical, paint, pelletizing iron ore, and waterproofing and more than 70% of the bentonite sold for foundry sand, and miscellaneous filler and extender applications. More than 50% of the bentonite sold for clarifying, decolorizing, and filtering of oils and greases was the nonswelling variety.

The major domestic markets for swelling bentonite were, in decreasing order, pet waste absorbents, drilling mud, foundry sand, iron ore pelletizing, and sealing and waterproofing. Major export markets for swelling bentonite were, in decreasing order, foundry sand, drilling mud, and iron ore pelletizing. The major domestic uses for nonswelling bentonite were, in descending order of tonnage, water treatment and filtering; foundry sand bond; clarifying, decolorizing, and filtering of oils and greases; waterproofing and sealing; adhesives; and animal feed.

Common Clay and Shale.—Common clay and shale was used most frequently in the manufacture of heavy-clay products (such as building brick, drain tile, flue linings, and terra cotta), lightweight aggregate, portland cement, sewer pipe, and structural tile (table 5). Consumption of common clay and shale decreased slightly to 24.5 Mt in 2005, almost unchanged from that of 2004. Brick manufacture remained the leading market for common clay and shale, followed by, in descending order of tonnage, lightweight aggregate and portland cement. Residential and nonresidential construction, on which the common clay and shale industry is dependent, increased in value to $1.12 trillion in 2005 from $1.03 trillion in 2004 (U.S. Census Bureau, 2006§).

Fire Clay.—Fire clays were used in grogs and calcines; high-alumina brick and specialties; ramming and gunning mixes; refractory products, such as firebrick and block; mortars and mixes; and saggers. Fire clays also were used to produce such items as brick and pottery.

Consumption of fire clay increased to 353,000 t in 2005 from 307,000 t in 2004 as a result of increased sales for heavy-clay product manufacture (table 6). Markets for fire clay were, in descending order of tonnage, portland cement, refractory mortar and cement, miscellaneous refractory product, and common brick applications.

Fuller's Earth.—Consumption of montmorillonite-type fuller's earth was 2.99 Mt in 2005 versus 3.02 Mt in 2004. Major domestic markets for montmorillonite were, in descending order of tonnage, pet waste absorbents; oil and grease absorbents; portland cement; clarifying, decolorizing, and filtering of oils and greases; pesticide carrier; miscellaneous fillers, extenders, and binders; animal feed; asphalt tile, miscellaneous absorbents; miscellaneous refractory products; and fertilizer carrier. The leading export market was pet waste absorbent (table 7).

Major markets for attapulgite were, in decreasing order, fertilizer carrier; miscellaneous filler and extender applications; drilling mud; absorbents; animal feed; miscellaneous refractory products; paint; clarifying, decolorizing, and filtering of mineral oils and greases; gypsum products; cosmetic, medical, pharmaceutical applications; and adhesives. Sales data were concealed to avoid disclosing company proprietary data.

Sales of the montmorillonite variety of fuller's earth accounted for more than 80% of sales of fuller's earth for asphalt tile; portland cement manufacture; clarifying, decolorizing, and filtering of oils and greases; oil and grease absorbents; pesticide carriers; pet waste absorbents; and exported products. Attapulgite accounted for most of the sales for adhesives; cosmetic, medical, and pharmaceutical applications; drilling mud; fertilizer carriers; gypsum products; and paint.

Kaolin.—Consumption of kaolin increased to 7.80 Mt in 2005 from 7.76 Mt in 2004 (table 8). The major domestic

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markets for kaolin were, in descending order of tonnage, paper coating and filler, refractory products, paint, fiberglass, rubber, miscellaneous fillers and extenders, catalyst manufacture, and plastic (table 11). Major domestic markets for kaolin from Georgia were, in descending order by tonnage, paper coating, paper filling, other ceramics, paint, refractory products, fiberglass, rubber, miscellaneous fillers and extenders, plastics, and catalyst manufacture. The major export market for Georgia kaolin was in paper applications (table 9). Owing to the reporting errors discussed in the "Kaolin" portion of the production section of this report, the domestic sales total in Georgia in 2004 should be increased by about 500,000 t. Major domestic markets for kaolin from South Carolina were, in descending order of tonnage, rubber, catalyst, brick, fiberglass, plastics, adhesives, and roofing granules (table 10). The major export market for kaolin from South Carolina was rubber applications.

Uses.—By application, consumption of clays was as follows:

Absorbent Uses.—Sales reported by producers for absorbent uses were 3.92 Mt in 2005. Fuller's earth accounted for 68% of the clay used for absorbents, followed by bentonite and a small amount of kaolin. Pet waste absorbents accounted for 90% of absorbent consumption, followed by miscellaneous absorbent applications and oil and grease absorbents.

Ceramics.—All varieties of clays were used in ceramics. Demand for clay in the manufacture of ceramics, ranging from china to sanitaryware to roofing granules, was 2.31 Mt in 2005. The leading ceramics markets were ceramic floor and wall tile (43%), sanitaryware (18%), miscellaneous ceramics (13%), roofing granules (12%), catalyst (8%), pottery (2%), quarry tile (1%), electrical porcelain (1%), and fine china (1%). Ball clay accounted for 47% of the clay used in ceramics, common clay and shale, 27%; and kaolin, 25%. Small amounts of bentonite also were used in the manufacture of ceramics. Ball clay dominated the electrical porcelain and sanitaryware markets. Common clay and shale was the predominant category of clay used in quarry tile and roofing granules. Kaolin dominated the catalyst market. Ball clay and common clay and shale were the predominant clays used in floor and wall tile manufacture, and ball clay and kaolin dominated the fine china market.

In 2005, apparent consumption of clay floor and wall tile in the United States was 303 million square meters valued at $3.08 billion compared with 293 million square meters valued at $2.86 billion in 2004. Domestic producers shipped 61.1 million square meters (658 million square feet) of clay floor and wall tile in 2005 compared with 64.6 million square meters (695 million square feet) in 2004. In 2005, exports were 3.44 million square meters valued at $31.5 million compared with 3.24 million square meters valued at $26.9 million in 2004. Imports of clay floor and wall tile were 245 million square meters valued at $2.26 billion in 2005, compared with 231 million square meters valued at $2.01 billion in 2004 (U.S. Census Bureau, 2006a, p. 12).

The U.S. Department of Commerce, International Trade Administration (2006§) reported that 31.5 million square meters valued at $218 million of glazed and unglazed ceramic tile with sides measuring less than 7 centimeters was imported compared with 29.2 million square meters valued at $198 million in 2004. Brazil, Italy, and Spain were the major sources of imported tile of these dimensions.

Imports of ceramic baths, bidets, flush tanks, lavatories, sinks, toilet bowls, and other ceramic sanitary fixtures increased in 2005. The U.S. Department of Commerce, International Trade Administration (2006§) reported imports to be 35.1 million units compared with 31.2 million units in 2004. China and Mexico were the major sources of imported sanitaryware.

Construction.—Common clays and shales were used to manufacture a wide variety of construction materials, including expanded aggregates, hydraulic cement, and structural clay products.

Expanded Clay and Shale.—Approximately 3.85 Mt of clay and shale was used in the production of lightweight aggregates in 2005 (table 12). All the clay used to manufacture lightweight aggregates was common clay and shale. Lightweight aggregates were used in concrete block, structural concrete, and highway surfacing, in decreasing order of tons consumed.

Hydraulic Cement.—Clays provide the alumina and silica required to manufacture hydraulic cements. In 2005, approximately 4.09 Mt of clays was consumed in the production of cement. In descending order of tonnage, common clay and shale, fuller's earth, fire clay, and kaolin were used in the manufacture of portland cement clinker. About 90% of the clay consumed by the cement industry was common clay and shale.

Structural Clay Products.—Approximately 15.4 Mt of clays was used in the manufacture of structural clay products, such as building brick, roofing tile, and sewer pipe. Common and face brick accounted for about 98% of this total (tables 5 and 13). Other markets were, in descending order of tonnage, flue linings, miscellaneous clay products, flower pots, sewer pipe, structural tile, and drain tile. About 99% of the clay used to manufacture structural clay products was common clay and shale. Small amounts of ball clay, bentonite, fire clay, and kaolin also were used.

In 2005, domestic producers shipped 9.42 billion building and face bricks compared with 9.39 billion bricks in 2004. About 175,000 t of vitrified clay sewer pipe and fittings valued at $72 million was shipped in 2005 compared with 148,000 t valued at $61.8 million in 2004 (U.S. Census Bureau, 2006a, p. 12).

Drilling Mud.—Sales of clays for drilling mud applications were 993,000 t (domestic) and 75,800 t (exported). Swelling-type bentonite accounted for 95% of the clay used in drilling mud. Fuller's earth also was used in drilling mud applications. Sales of drilling muds increased slightly in 2005 as the result of increased oil drilling activity. The average number of rotary rigs in Canada and the United States operating in 2005 was 1,840 per month compared with 1,560 per month in 2004 (Baker Hughes Inc., 2006§).

Fillers, Extenders, and Binders.—Clays are used as fillers, extenders, and binders in a wide variety of products, such as adhesives, flooring products, paint, paper, and rubber. About 4.62 Mt of clays was sold for use as fillers, extenders, and binders in the United States. An additional 1.98 Mt of clays was exported for filler and extender applications. Paper coating and filling accounted for 62% of domestic sales, followed by miscellaneous filler and extenders (11%), paint (11%), rubber (6%), and plastics (3%). Adhesives; animal feed; asphalt emulsion; cosmetic, medical, pharmaceutical; and fertilizer and pesticide carriers each accounted for less than 2% of the fillers and extenders markets.

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Kaolin accounted for approximately 90% of the clay used in domestic and export filler and extender applications, followed by fuller's earth (5%), common clay and shale (3%), bentonite (2%), and ball clay (1%). Bentonite was the predominant clay used for cosmetic, medical, and pharmaceutical applications; fuller's earth dominated in fertilizer and pesticide applications. Kaolin was the predominant clay used for adhesives, asphalt emulsion, paint, paper, plastics, and rubber markets.

The U.S. Census Bureau (2006b) reported shipments of paint and coatings for 2005 to be 5.79 billion liters (1.53 billion gallons), unchanged from that of 2004. Of this amount, architectural paints, the major market for paint-grade fillers, was 3.01 billion liters (795 million gallons) in 2005 compared with 3.04 billion liters (804 million gallons) in 2004.

Fiberglass.—Sales, including exports, to the fiberglass and mineral wool industry were 407,000 t. Most of the clay used for fiberglass was kaolin. While industry statistics are not available on fiberglass production, industrial sand (ground and unground) used for the production of fiberglass was 1.66 Mt in 2005 compared with 1.74 Mt in 2004 (T.P. Dolley, physical scientist, U.S. Geological Survey, written commun., September 7, 2006).

Iron Ore Pelletizing.—Sales of clays for iron ore pelletizing applications reported by producers were 595,000 t (579,000 t used domestically and 15,500 t exported). Swelling bentonite was the only type of clay used for this application.

Paper Products.—Kaolin accounted for all the clay sales used for paper coating (2.31 Mt sold domestically and 1.74 Mt exported) and essentially all the clay used for paper filling (574,000 t sold domestically and 121,000 t exported).

Refractory Products.—Producers reported that 2.49 Mt of clays was used for the manufacture of refractory products in 2005 (1.39 Mt with foundry sand excluded). This compares with 2.77 Mt and 1.62 Mt, respectively, in 2004. Foundry sand accounted for 39% of domestic sales and all export sales under the refractory category. Other refractory markets for clays were firebrick; grogs and calcines; high-alumina brick and kiln furniture; plug, tap, and wad products; and refractory mortar and cement. About 205,000 t was exported for refractory applications.

Bentonite accounted for 1.1 Mt of refractory sales (893,000 t domestic and 205,000 t exported), followed by common clay and shale (696,000 t), kaolin (498,000 t), fire clay (163,000 t), and ball clay and fuller's earth combined (37,300 t).

The U.S. Census Bureau (2006c) reported clay refractory shipments valued at $855 million in 2005 compared with $781 million in 2004. Fireclay, high alumina, and insulating brick shapes accounted for $403 million of the shipments (642,000 t), followed by unshaped clay refractory bonding mortars (597,000 t valued at $358 million). The remainder was other refractory clay raw materials and refractory materials sold in lump or ground form.

Prices

Increased energy and other operating costs continued to affect kaolin producers. Energy costs doubled or tripled between 2002 and 2005 (McGinley, 2005§). Consequently, major clay producers again announced price increases for ball clay, fuller's earth, and kaolin products. Several of the unit values given below for specific clay types are slightly lower than in 2004 despite announcements of energy surcharges and price increases by many producers. Some producers may have underreported their sales values in 2005; unit values lower than those of 2004 probably should be increased by 3% to 5% to account for energy surcharges instituted in 2005.

Ball Clay.—The average value for ball clay reported by domestic producers was $43.67 per metric ton. The average values for exported and imported ball clay were $63 per ton and $283 per ton, respectively.

Bentonite.—The average value reported by domestic producers for nonswelling bentonite was $47.94 per ton. The average value for swelling bentonite was $45.53 per ton. The average value for all bentonite was $45.68 per ton. The average value of exported bentonite was $116 per ton. The average value of imported bentonite was $355 per ton.

The price, ex-works, Wyoming, crude, bulk, railcars, was $33 to $69 per ton; foundry-grade, bagged, railcars, $55 to $84 per ton; and American Petroleum Institute (API)-grade, bagged, railcars, $47 to $58 per ton. The price for bentonite, India, crushed, dried, loose in bulk, was $43 to $53 per ton for API-grade; $32 to $40 per ton for pet litter grade; and $59 to $76 per ton for foundry grade (Industrial Minerals, 2005a).

Common Clay and Shale.—The average value for all common clay and shale produced in the United States and Puerto Rico was $7.21 per ton. The average value of clay and shale used in lightweight aggregate was $22.17 per ton. The value for lightweight aggregate is an estimate of the clay value. Average prices for lightweight aggregate produced from clay and shale ranged from $30 to $50 per ton for most applications.

Fire Clay.—The average value for fire clay reported by domestic producers was $30.22 per ton. The average value of exported fire clay was $94 per ton. The average of imported fire clay was $310 per ton.

Fuller's Earth.—The average value of attapulgite-type fuller's earth was concealed to avoid revealing company proprietary data but increased slightly in 2005. The average value of montmorillonite-type fuller's earth was $101.22 per ton. The average value of exported fuller's earth was $246 per ton. The average value of imported fuller's earth was $143 per ton.

Kaolin.—The average value of kaolin was $110.25 per ton for all kaolin grades. The average value for airfloat was $64.53 per ton; refractory-grade (high-temperature calcined), $31.31 per ton; pigment-grade (low-temperature calcined), $299.20 per ton; all types of calcined, $202.34 per ton; delaminated, $111.90 per ton; water washed, $97.66 per ton; and unprocessed, 5.30 per ton. Adjusting for delaminated and water washed kaolin reporting error, as discussed in the kaolin portion of the "Production" section, results in an average value of about $115 per ton for delaminated kaolin and $109 per ton for water-washed kaolin. The average value of exported kaolin was $168 per ton. The average value of the imported kaolin was $153 per ton.

The price, ex-works, Georgia, filler, bulk, was $88 to $110 per ton; coating, bulk, $94 to $204 per ton; sanitaryware-grade, bagged, $72 to $83 per ton; tableware-grade, bagged, $138 per ton; and calcined, bulk, $353 to $413 per ton (Industrial Minerals, 2005a).

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Foreign Trade

Ball Clay.—Ball clay exports increased to 141,000 t valued at $8.84 million in 2005 compared with 107,000 t valued at $8.2 million in 2004, according to the U.S. Census Bureau (table 14). Producers reported exports of 204,000 t. Some of the extra tonnage reported by ball clay producers was likely accounted for by shipments to Mexico. Exports to Mexico reported by the U.S. Census Bureau typically are less than indicated by ball clay producers. The water weight of slurry shipments (about 30% to 35% of the shipment weight) may also account for a portion of the extra tonnage reported by producers. Imports were 667 t of ball clay valued at $261,000 (table 15).

Bentonite.—Bentonite exports decreased to 847,000 t valued at $98.5 million in 2005 from 915,000 t valued at $105 million in 2004 (table 14). Exports increased by 51,000 t to Canada, but decreased by 95,000 t to Japan, 26,000 t to the United Kingdom and 20,000 t to Taiwan. Exports to several countries increased by small amounts. Domestic bentonite producers reported exports of 434,000 t (table 4). The large discrepancy between data reported by producers and the U.S. Census Bureau resulted from producers including most of the exports destined for Canadian and Mexican markets (372,000 t) under domestic sales. In addition, some bentonite is packaged domestically and then exported as a finished product, such as cat litter. Sales through U.S. mineral brokers, where producers do not know if the bentonite is used domestically or exported, could also explain part of the discrepancy.

Bentonite imports consisted mainly of untreated bentonite clay and chemically or artificially activated materials. Imports of untreated bentonite were 10,400 t valued at $3.55 million. Imports of chemically activated material were 16,000 t valued at $10.3 million (table 15).

Fire Clay.—In 2005, exports increased to 368,000 t valued at $34.4 million compared with 332,000 t valued at $32.3 million in 2004 (table 14). About 49% of the exports reported by the U.S. Census Bureau under the Harmonized Tariff Schedule of the United States code for fire clay was thought to be refractory-grade kaolin rather than fire clay based on the locations of ports from which the material was exported. Imports were 429 t valued at $156,000 (table 15).

Fuller's Earth.—In 2005, exports increased to 54,700 t valued at $13.5 million compared with 49,000 t valued at $10.3 million in 2004 (table 14). Imports of decolorizing earth and fuller's earth were 2,450 t valued at $286,000 (table 15).

Kaolin.—In 2005, 3.58 Mt of kaolin valued at $601 million was exported compared with 3.64 Mt valued at $600 million in 2004 (table 14). Producers reported exports of 2.15 Mt (table 11). Of the 1.43 Mt difference, probably much of the 641,000 t destined for Canada and 346,000 t for Mexico was reported under domestic consumption. Sales through U.S. mineral brokers, where producers do not know if the kaolin is used domestically or exported, could also explain part of the discrepancy.

Kaolin imports increased to 262,000 t valued at $40.2 million in 2005 compared with 205,000 t valued at $38.6 million in 2004 (table 15). About 93% of the kaolin was imported from Brazil followed by the United Kingdom. Imports from Brazil were primarily for paper coating applications, and those from the United Kingdom were primarily for paper filler applications.

World Review

World production of bentonite was approximately 11.7 Mt (table 16). Fuller's earth production was estimated to be 5.61 Mt. This tonnage excludes U.S. attapulgite-type fuller's earth production and production data from Israel, which is thought to have been misclassified as fuller's earth in 2002 through 2005 (table 17). Production of bentonite and fuller's earth combined for Israel is probably less than 5,000 t/yr, based on trade industry reports. Kaolin production was 44.7 Mt (table 18). The world production data for kaolin including common clay from Colombia, ball clay from Australia, and crude kaolin ore production tonnages from many other countries. Sales of processed kaolin were estimated to be about 24.6 Mt, after excluding 8.4 Mt of common clay from the total for Colombia and 4 Mt for Uzbekistan, 3.4 Mt for the Czech Republic, 3.1 Mt for Germany, 600,000 t for Iran, 300,000 t for Mexico, 200,000 t for Egypt, and 100,000 t for Australia to account for processing losses. The United States continued to be the leading supplier of processed clay for sale, followed by Greece, Turkey, and the Commonwealth of Independent States for bentonite; Spain for fuller's earth; and the United Kingdom and Brazil for kaolin. Fuller's earth production reported for Germany probably represents double counting of bentonite as fuller's earth. Spain led all countries in the production of sepiolite.

Denmark.—NCC Group, a Swedish construction company, began construction of a 60,000-t/yr processing plant near Svendborg. NCC mined calcium bentonite and sold unprocessed bentonite for civil engineering applications. The company decided to construct the new plant so it can sell processed bentonite for such applications as foundry sand, pet litter, and other specialty markets (Mining Engineering, 2005).

Outlook

Construction-oriented markets for clay-base products, such as brick, cement, ceramic tile, lightweight aggregate, and whiteware, remain strong, although there are signs of a slowdown of housing sales in the United States. Increase in the sales of ball clay and common clay probably will slow slightly in the coming years, but no significant declines in sales are anticipated. Sales of fire clay probably will decline for refractory products, but use of fire clay for the manufacture of cement and heavy–clay products may enable sales to rebound from the declines in recent years.

The overall market for fuller's earth may increase slightly in the next couple of years. Demand for fuller's earth increased in 2005 for clarifying, decolorizing, and filtering greases and oils, and this trend is expected to continue for the short term. Other markets for fuller's earth such as agriculture and pet litter are variable from year-to-year, but pet litter, the largest market for fuller's earth, continues to exhibit an upward trend, likely to continue for at least the next 2 to 3 years.

The International Iron and Steel Institute indicated that world production of steel increased 8.8% in 2004. With about 25% of

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world iron ore pelletized, demand for bentonite for pelletizing has also increased. In 2004, pelletizing accounted for about 15% and 21% of total bentonite demand in the United States and Europe, respectively. Despite increased sales for pelletizing in 2004 and 2005, sales eventually are expected to decline with the phasing in of new refining technologies that do not require the use of pelletized iron ore (Burke, 2005a).

Continued high levels of drilling for oil are expected to result in the continued high demand for bentonite for drilling mud applications for the near future. Despite this, long-term demand is expected to decline because prices for drilling-grade bentonite have remained low; a significant portion of new drilling has focused on improving petroleum recovery in existing deposits (which does not require bentonite-base drilling muds); many new polymer drilling fluid additives are designed to remove formation clays, and that excludes the use of bentonite in the drilling fluid; and use of more environmentally friendly synthetic drilling muds discourages the use of bentonite drilling fluids (Burke, 2005b). The gradual increase in sales of bentonite for pet litter markets is anticipated to continue for the near future. Other markets for bentonite have been unchanged for the past few years and are likely to remain so for the short term.

Construction-oriented markets for kaolin such as ceramic tile, fiberglass, paint, and sanitaryware probably will maintain sales in the next few years because of the continuing strength of the U.S. housing market. The largest markets for kaolin, paper coating and filling, are beginning to stabilize after several years of significant declines. The paper filler market declined largely because of competition from calcium carbonate from about 1990 to 2000. Paper coating also suffered to a lesser extent from the competition from calcium carbonate but also from a slumping paper industry. Shipments of paper have increased in the past couple of years, and paper capacity is more in-line with demand in the North American market. These factors should result in a more stable paper market for domestic producers. However, domestic producers continue to face stiff competition from kaolin imports from Brazil (including from some of their own affiliates) to the North American paper market. Sales by domestic producers to the paper industry may decline only slightly for the next year or two. Overall sales of kaolin by U.S. producers for all markets probably are going to remain relatively unchanged during the next couple of years.

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TABLE 1
SALIENT U.S. CLAY STATISTICS[1, 2]

(Thousand metric tons and thousand dollars)

	2001	2002	2003	2004	2005
Domestic clays sold or used by producers:					
Quantity	39,600	39,300	40,000	41,200	41,700
Value	1,510,000	1,580,000	1,660,000	1,680,000	1,650,000
Exports:					
Quantity	4,970	4,960	5,130	5,630	5,620
Value	836,000	817,000	859,000	936,000	929,000
Imports for consumption:					
Quantity	148	217	279	251	301
Value	33,900	39,400	51,200	61,700	59,400

[1]Excludes Puerto Rico.
[2]Data are rounded to no more than three significant digits.

TABLE 2
CLAYS SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY STATE[1, 2]

(Thousand metric tons and thousand dollars)

	2004		2005	
State	Quantity	Value	Quantity	Value
Alabama	2,220	32,700	2,470	34,600
Arizona	W	W	80	1,720
Arkansas	1,150	1,510	1,280	2,760
California	1,260	23,300	1,260	44,300
Colorado	249	1,510	258	1,680
Connecticut	87	W	89	337
Florida	31	3,280	312	43,300
Georgia	9,720	1,040,000	10,100	981,000
Illinois	465	1,390	344	26,200
Indiana	729	8,910	823	14,500
Iowa	325	1,150	630	4,740
Kansas	621	7,460	680	5,620
Kentucky	978	4,510	1,150	8,930
Louisiana	399	11,000	416	13,100
Maine	49	W	50	127
Maryland	262	571	317	686
Massachusetts	36	W	37	327
Michigan	605	3,070	334	514
Minnesota	20	22	20	22
Mississippi	992	37,900	1,270	50,800
Missouri	911	3,290	1,460	38,300
Montana	102	8,400	135	5,460
Nebraska	133	W	160	606
Nevada	25	4,520	67	6,110
New Jersey	W	122	83	133
New Mexico	34	177	36	221
New York	756	10,900	785	11,700
North Carolina	2,290	13,600	2,210	14,400
North Dakota	W	189	76	279
Ohio	1,360	7,480	1,360	9,180

See footnotes at end of table.

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TABLE 2—Continued
CLAYS SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY STATE[1, 2]

(Thousand metric tons and thousand dollars)

State	2004		2005	
	Quantity	Value	Quantity	Value
Oklahoma	1,150	2,410	903	2,520
Oregon	W	450	79	1,090
Pennsylvania	822	3,270	705	3,460
South Carolina	1,330	22,500	1,360	22,200
South Dakota	188	743	183	744
Tennessee	1,130	37,500	1,210	41,000
Texas	2,160	8,890	2,680	28,600
Utah	515	5,600	541	8,990
Virginia	994	4,640	1,240	32,200
Washington	W	W	87	211
West Virginia	161	441	186	524
Wyoming	3,550	151,000	4,220	190,000
Total	41,200	1,680,000	41,700	1,650,000

W Withheld to avoid disclosing company proprietary data; included in " Total."

[1]Excludes Puerto Rico.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 3
BALL CLAY SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY TYPE[1]

(Thousand metric tons and thousand dollars)

	2004		2005	
	Quantity	Value	Quantity	Value
Type:				
Airfloat	537	28,600	677	31,700
Water-slurried	205 r	9,790 r	145	7,090
Unprocessed	482 r	15,700 r	388	14,100
Total	1,220	54,100	1,210	52,900
Use:				
Fillers, extenders, binders[2]	86	NA	51	NA
Floor and wall tile	428	NA	485	NA
Miscellaneous ceramics[3]	203	NA	132	NA
Pottery	26	NA	18	NA
Refractories[4]	W	NA	W	NA
Sanitaryware	322	NA	297	NA
Miscellaneous[5]	45	NA	23	NA
Exports[6]	114	NA	204	NA
Total	1,220	54,100	1,210	52,900

rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data; included in "Miscellaneous."

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes adhesives, animal feed, asphalt tile, asphalt emulsions, gypsum, paper filling, pesticides and related products, plastics, rubber, and other fillers, extenders, and binders.

[3]Includes catalysts, electrical porcelain, fiberglass, fine china/dinnerware, glass, mineral wool, roofing granules, and miscellaneous ceramics.

[4]Includes firebrick, blocks, shapes, high-alumina specialties, and kiln furniture.

[5]Includes heavy clay products, waterproofing seals, other unknown uses and data represented by symbol W.

[6]Includes ceramics and glass and floor and wall tile.

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TABLE 4

BENTONITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY TYPE AND USE[1]

(Thousand metric tons and thousand dollars)

	2004		2005	
	Quantity	Value	Quantity	Value
Type:				
Nonswelling	320	14,200	300	14,400
Swelling	4,230 r	192,000 r	4,410	201,000
Total	4,550 r	206,000 r	4,710	215,000
Use:				
Domestic:				
Absorbents:				
Pet waste absorbents	1,040 r	NA	1,240	NA
Other absorbents	W	NA	W	NA
Adhesives	2	NA	2	NA
Animal feed	51 r	NA	53	NA
Ceramics (except refractories)[2]	W	NA	W	NA
Drilling mud	847 r	NA	945	NA
Filler and extender applications[3]	39	NA	61	NA
Filtering, clarifying, decolorizing	W	NA	W	NA
Foundry sand	891 r	NA	893	NA
Pelletizing (iron ore)[4]	614 r	NA	579	NA
Miscellaneous refractories	--	NA	--	NA
Miscellaneous[5]	412 r	NA	356	NA
Waterproofing and sealing	193	NA	176	NA
Total	4,090 r	NA	4,310	NA
Exports:				
Drilling mud	59 r	NA	76	NA
Foundry sand	258 r	NA	205	NA
Other[6]	151 r	NA	123	NA
Total	468 r	NA	404	NA
Grand total	4,550 r	206,000 r	4,710	215,000

rRevised. NA Not available. W Withheld to avoid disclosing company proprietry data; included with "Miscellaneous." -- Zero.

[1]Data are rounded to no more than three significant digits, may not add to totals shown.

[2]Includes catalysts and pottery.

[3]Includes asphalt tiles, cosmetics, ink, medical, miscellaneous fillers and extenders applications, paint, paper coating, paper filling, pesticides and related products, pharmaceuticals, and plastics.

[4]Excludes shipments to Canada. Total sales in North America were 682,000 metric tons (t) in 2004 and 595,000 metric tons (t) in 2005.

[5]Includes chemical manufacturing, heavy clay products, other unknown uses and data represented by symbol W.

[6]Includes absorbents, fillers and extenders, miscellaneous refractories, pelletizing, and other unknown uses.

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TABLE 5
COMMON CLAY AND SHALE SOLD OR USED BY PRODUCERS
IN THE UNITED STATES, BY STATE AND USE[1, 2]

(Thousand metric tons and thousand dollars)

	2004		2005	
	Quantity	Value	Quantity	Value
State:				
Alabama	2,120	29,600	2,280	29,000
Arkansas	1,150	1,510	1,210	1,900
California	1,230	20,700	1,010	16,600
Georgia	1,550	8,710	1,530	8,730
Indiana	729	8,910	809	13,500
Kansas	621	7,460	654	4,590
Kentucky	978	4,510	1,060	4,370
Michigan	605	3,070	334	514
Mississippi	610	2,700	642	2,860
Missouri	911	3,290	822	3,400
New York	756	10,900	785	11,700
North Carolina	2,260	12,900	2,180	13,900
Ohio	1,360	7,480	1,310	6,880
Oklahoma	1,150	2,410	903	2,520
Pennsylvania	822	3,270	705	3,460
South Carolina	1,040	2,860	1,020	3,610
Texas	2,160	8,890	2,340	8,680
Virginia	994	4,640	982	4,690
Other[3]	3,520 r	29,400	3,900	35,500
Total	24,600	173,000	24,500	176,000
Use:				
Ceramics and glass[4]	405	NA	217	NA
Floor and wall tile:				
Ceramic	370	NA	374	NA
Other[5]	39	NA	35	NA
Heavy clay products:				
Brick, extruded	12,700	NA	13,200	NA
Brick, other	1,650	NA	1,680	NA
Other[6]	237	NA	273	NA
Lightweight aggregate:				
Concrete block	2,160	NA	1,950	NA
Highway surfacing	323	NA	325	NA
Structural concrete	758	NA	903	NA
Miscellaneous	522	NA	666	NA
Portland and other cements	4,200	NA	3,690	NA
Refractories[7]	749	NA	696	NA
Miscellaneous[8]	458	NA	446	NA
Total	24,600	173,000	24,500	176,000

rRevised. NA Not available.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Excludes Puerto Rico.

[3]Includes all other States except Alaska, Delaware, Hawaii, Idaho, Nevada, New Hampshire, Rhode Island, Vermont, and Wisconsin.

[4]Includes pottery and roofing granules.

[5]Includes quarry tile and miscellaneous floor and wall tiles.

[6]Includes drain tile, flower pots, roofing tile, sewer pipe, structural tile, and miscellaneous clay products.

[7]Includes firebrick, blocks and shapes; mortar and cement, grogs and calcines; and miscellaneous refractories.

[8]Includes exports; miscellaneous civil engineering and sealings; miscellaneous fillers, extenders, and binders; and other unknown uses.

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TABLE 6

FIRE CLAY SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE AND USE[1]

(Thousand metric tons and thousand dollars)

	2004		2005	
	Quantity	Value	Quantity	Value
Production	307	8,510	353	10,700
Use:				
Heavy clay products and lightweight aggregates[2]	142	NA	190	NA
Refractories:				
Firebrick, block, shapes	--	NA	--	NA
Other refractories[3]	165	NA	163	NA
Miscellaneous[4]	-- r	NA	--	
Total	307	8,510	353	10,700

rRevised. NA Not available. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes common brick, miscellaneous lightweight aggregates, portland cement, and terra cotta (2004).

[3]Includes foundry sand, grogs and calcines, kiln furniture (2005), mortar and cement, and miscellaneous refractories.

[4]Includes miscellaneous lightweight aggregates, and other unknown uses.

TABLE 7

FULLER'S EARTH SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY TYPE AND USE[1]

(Thousand metric tons and thousand dollars)

	2004		2005	
	Quantity	Value	Quantity[2]	Value[2]
Type:				
Attapulgite[3]	237	30,100	W	W
Montmorillonite	3,020	299,000	2,990	302,000
Total	3,260	329,000	2,990	302,000
Use:				
Absorbents:				
Oil and grease absorbent	295	NA	283	NA
Pet waste absorbent	2,250	NA	2,295	NA
Animal feed	(4)	NA	(4)	NA
Fertilizers	46	NA	(4)	NA
Fillers, extenders, binders[5]	127	NA	66	NA
Filtering, clarifying, and decolorizing animal, mineral, and vegetable oils and greases	67	NA	(4)	NA
Pesticides and related products	(4)	NA	(4)	NA
Miscellaneous[6]	477	NA	376	NA
Exports[7]	(4)	NA	(4)	NA
Total	3,260	329,000	2,990	302,000

NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Excludes attapulgite-type fuller's earth.

[3]Primarily gellant-grade fuller's earth. More information can be found in the "Fuller's Earth" portion of the production section of this report.

[4]Withheld to avoid disclosing company proprietary data; included under "Miscellaneous."

[5]Includes adhesives, asphalt emulsions, asphalt tiles, gypsum products, medical, pharmaceuticals and cosmetics, paints, paper coating, textiles, and other unknown uses in 2004 and asphalt tile and other unknown uses in 2005.

[6]Includes animal feed, drilling mud, fertilizers, filtering, pesticides, portland cement, refractories, roofing granules, and other unknown uses in 2004 and animal feed, fertilizers, filtering, pesticides, portland cement and refractories in 2005 and exports.

[7]Includes absorbents; fillers, extenders, and binders; floor and wall tiles; and refractories in 2004 and pet waste absorbents in 2005.

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TABLE 8
KAOLIN SOLD OR USED BY PRODUCERS IN THE UNITED STATES,
BY STATE AND KIND[1]

(Thousand metric tons and thousand dollars)

	2004		2005	
	Quantity	Value	Quantity	Value
State:				
Georgia	6,780	889,000	7,190	825,000
South Carolina	296	19,600	287	17,700
Other[2]	684	27,200	326	17,100
Total	7,760	936,000	7,800	860,000
Kind:				
Airfloat	1,150	62,400	1,270	81,900
Calcined:[3]				
Pigment-grade	853	250,000	837	250,000
Refractory-grade	547	16,500	474	14,800
Total	1,400	267,000	1,310	265,000
Delaminated	1,240	156,000	1,010 [4]	113,000 [4]
Unprocessed	101	1,850	139	2,130
Water washed	3,870	449,000	4,070 [4]	398,000 [4]
Grand total	7,760	936,000	7,800	860,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes Alabama, Arkansas, California, Florida, Nevada, North Carolina, Tennessee, and Texas.

[3]Pigment-grade kaolin is low-temperature calcined kaolin, and refractory-grade kaolin is high-temperature calcined kaolin.

[4]Some delaminated kaolin production included under "Waterwashed." More information can be found in the "Kaolin" portion of the production section of this report.

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TABLE 9
GEORGIA KAOLIN SOLD OR USED BY PRODUCERS, BY KIND[1]

(Thousand metric tons and thousand dollars)

	2004		2005	
	Quantity	Value	Quantity	Value
Kind:				
Airfloat	851	41,300	1,010	61,700
Calcined[2]	906	245,000	1,190	255,000
Delaminated	1,240	156,000	1,010	113,000
Unprocessed	W	W	W	W
Water washed	3,780	447,000	3,970	396,000
Total	6,780	889,000	7,180	826,000
Use:				
Domestic:				
Ceramics and glass:				
Catalysts (oil-refining)	(3)	NA	(3)	NA
Fiberglass	290	NA	348	NA
Roofing granules	(3)	NA	(3)	NA
Sanitaryware	(3)	NA	(3)	NA
Other[4]	399 r	NA	425	NA
Fillers, extenders, binders:				
Adhesives	40	NA	18	NA
Paint	273	NA	423	NA
Paper coating	2,470	NA	2,310	NA
Paper filling	465	NA	574	NA
Plastic	85	NA	139	NA
Rubber	95	NA	206	NA
Other[5]	78	NA	180	NA
Heavy clay products[6]	(7)	NA	(7)	NA
Refractories[8]	266	NA	413	NA
Undistributed[9]	51 r	NA	85	NA
Total	4,510	NA	5,120	NA
Exports:				
Paint	73	NA	55	NA
Paper coating[10]	1,920	NA	1,740	NA
Paper filling[10]	129	NA	121	NA
Rubber	11	NA	14	NA
Undistributed[11]	126	NA	135	NA
Total	2,260	NA	2,070	NA
Grand total	6,780	889,000	7,190	825,000

NA Not applicable. rRevised. W Withheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes pigment- and refractory-grade calcined kaolin.

[3]Withheld to avoid disclosing company proprietary data; included in Domestic: "Ceramics and glass: Other."

[4]Includes catalysts (oil-refining), electrical porcelain, fine china/dinnerware, pottery, miscellaneous ceramics, roofing granules, and sanitaryware.

[5]Includes animal feed, asphalt tile, fertilizers, gypsum products, medical, pharmaceuticals and cosmetics, pesticides and related products, textiles, and miscellaneous fillers, extenders, and binders.

[6]Includes brick (common and face), portland cement, and miscellaneous clay products.

[7]Withheld to avoid disclosing company proprietary data; included in "Domestic: Undistributed."

[8]Includes firebricks, blocks and shapes, grogs and calcines, high-alumina specialties, kiln furniture, and miscellaneous refractories.

[9]Includes absorbents, chemical manufacturing, floor and wall tiles, heavy clay products, waterproofing seals, and other unknown uses.

[10]Some export sales may be included under domestic sales.

[11]Includes adhesives, catalysts (oil-refining), fiberglass, sanitaryware; miscellaneous fillers, extenders, and binders; portland cement; and miscellaneous refractories.

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TABLE 10
SOUTH CAROLINA KAOLIN SOLD OR USED BY PRODUCERS, BY USE[1]

(Thousand metric tons and thousand dollars)

	2004		2005	
	Quantity	Value	Quantity	Value
Kind:				
Airfloat[2]	296	19,600	287	17,700
Unprocessed[3]	W	W	W	W
Total	296	19,600	287	17,700
Use:				
Adhesives	16	NA	10	NA
Ceramics[4]	107	NA	86	NA
Rubber	88	NA	87	NA
Refractories[5]	6	NA	2	NA
Other uses[6]	52	NA	78	NA
Exports[7]	27	NA	24	NA
Total	296	19,600	287	17,700

NA Not available. W Withheld to avoid disclosing company proprietary data; included in "Airfloat."

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes unprocessed kaolin.

[3]Includes calcined kaolin.

[4]Includes catalysts (oil-refining), fine china/dinnerware, glazes, glass, and enamels, pottery, roofing granules, sanitaryware, and miscellaneous ceramics.

[5]Includes firebrick, blocks and shapes, and miscellaneous refractories.

[6]Includes asphalt tile; brick (common and face); catalysts (oil refining); chemical manufacturing; civil engineering and sealings; drilling mud; fillers, extenders, and binders; heavy clay products; lightweight aggregates; paints; and plastics.

[7]Includes refactories and fillers, extenders, and binders.

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TABLE 11

KAOLIN SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE[1]

(Thousand metric tons)

Use	2004	2005
Domestic:		
Ceramics:		
Catalyst (oil and gas refining)	182 r	180
Electrical porcelain	W	W
Fine china and dinnerware	25	13
Floor and wall tile	71	97
Pottery	9	6
Roofing granules	71	65
Sanitaryware	33	48
Miscellaneous	W	106
Chemical manufacture	60	84
Civil engineering	W	W
Fiberglass, mineral wool	317	367
Fillers, extenders, binders:		
Adhesive	56	28
Fertilizer	W	W
Medical, pharmaceutical, cosmetic	1	1
Paint	313	445
Paper coating	2,470	2,310
Paper filling	465	574
Pesticide	W	W
Plastic	104	152
Rubber	183	290
Miscellaneous	79	182
Heavy clay products:		
Brick, common and face	97	118
Portland cement	57	80
Refractories[2]	732	498
Miscellaneous applications	142	5
Total	5,470 r	5,650
Exports:		
Ceramics	(3)	(3)
Paint	73	72
Paper coating	1,920	1,740
Paper filling	129	121
Rubber	38	38
Miscellaneous	128	176
Total	2,290	2,150
Grand total	7,760	7,800

rRevised. W Withheld to avoid disclosing company proprietary data; included in "Domestic: Ceramics: Miscellaneous applications."

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes firebrick (blocks and shapes), grogs and calcines, high-alumina kaolin (brick and specialties), kiln furniture, and miscellaneous refractories.

[3]Withheld to avoid disclosing company proprietary data; included in "Exports: miscellaneous."

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TABLE 12
COMMON CLAY AND SHALE USED IN LIGHTWEIGHT AGGREGATE
PRODUCTION IN THE UNITED STATES BY STATE[1]

(Thousand metric tons and thousand dollars)

State	Concrete block	Structural concrete	Other[2]	Total Quantity	Total Value[e]
2004:					
Alabama	759	54	90	904	24,200
Arizona	--	17	--	17	19
Arkansas	425	--	--	425	704
California	39	214	--	253	11,200
Florida[e]	68	23	--	91	1,280
Indiana[e]	130	35	71	236	7,500
Kansas	--	--	67	67	931
Kentucky[e]	109	36	--	145	557
Louisiana[e]	136	43	94	273	10,500
Missouri	--	--	101	101	1,500
New York[e]	82	96	--	178	7,840
North Carolina[e]	144	--	10	154	1,940
Ohio[e]	149	8	--	157	764
Oklahoma[e]	22	3	--	25	659
Texas[e]	49	157	253	459	2,520
Utah	49	71	159	279	5,210
Total	2,160	758	845	3,760	77,300
2005:					
Alabama	575	42	78	695	22,900
Arkansas	417	--	--	417	1,010
California	21	265	--	286	14,100
Indiana[e]	113	36	91	240	11,400
Kansas	--	--	70	70	972
Kentucky[e]	143	48	48	239	683
Louisiana[e]	140	32	125	297	12,600
Missouri	--	--	113	113	1,680
Nebraska	--	--	(3)	(3)	2
New York	220	233	--	454	8,900
North Carolina[e]	--	--	10	10	11
Ohio[e]	134	8	17	159	701
Oklahoma[e]	43	6	--	49	1,300
Texas[e]	49	162	265	476	2,730
Utah	96	71	173	340	6,330
Total	1,950	903	990	3,850	85,300

[e]Estimated. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Included highway surfacing.

[3]Less than ½ unit.

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TABLE 13
COMMON CLAY AND SHALE USED IN BUILDING BRICK PRODUCTION IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars)

State	2004		2005	
	Quantity	Value[e]	Quantity	Value[e]
Alabama	568	1,820	1,290	6,290
Arkansas	460	518	480	548
California	314	1,010	307	1,000
Colorado	199	1,320	222	1,460
Georgia	1,390	7,640	1,370	7,660
Illinois	240	1,310	W	508
Kentucky[3]	464	2,070	429	1,660
Maryland	194	264	248	374
Mississippi	534	2,570	565	2,730
North Carolina	2,030	6,200	2,120	13,800
Ohio	826	4,550	752	4,320
Oklahoma	834	1,310	788	1,030
Pennsylvania	768	3,070	643	3,270
South Carolina	760	1,400	810	2,300
Texas	967	4,060	1,140	3,500
Other[4]	4,040 r	20,300	4,000	17,700
Total	14,600 r	59,500	15,200	68,100

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Other."

[1]Includes extruded and other brick.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Extruded brick only.

[4]Includes all other States except Alaska, Arizona, Connecticut, Maine, Nevada, New Hampshire, Rhode Island, Vermont, and Wisconsin and data represented by symbol W.

TABLE 14
U.S. EXPORTS OF CLAYS IN 2005, BY KIND[1]

(Thousand metric tons and thousand dollars)

Material	2004		2005		Principal destinations, 2005
	Quantity	Value	Quantity	Value	
Ball clay	107	8,200	141	8,840	Canada, 27%; Mexico, 22%; Finland, 16%.
Bentonite	915	105,000	847	98,500	Canada, 40%; Japan, 17%; Saudi Arabia, 6%.
Fire clay	332	32,300	368	34,400	Mexico, 50%; Luxembourg, 27%.
Fuller's earth	49	10,300	55	13,500	Netherlands, 20%; Canada, 13%; Mexico, 5%. Colombia, 4%.
Kaolin	3,640	600,000	3,580	601,000	Japan, 23%; Canada, 17%; China, 8%; Finland, 6%. Mexico,10%; Taiwan, 6%.
Clays, n.e.c.	586	181,000	634	173,000	Canada, 55%; Mexico, 9%; Japan, 6%.
Total	5,630	936,000	5,620	929,000	XX

XX Not applicable.

[1]Data are rounded to no more than three significant digits.

Source: U.S. Census Bureau.

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TABLE 15
U.S. IMPORTS FOR CONSUMPTION OF CLAY IN 2005, BY KIND[1]

(Thousand metric tons and thousand dollars)

Material	2004		2005		Principal sources, 2005
	Quantity	Value	Quantity	Value	
China clay or kaolin	205	38,600	262	40,200	Brazil, 93%; United Kingdom, 6%.
Fire clay	6	1,680	(2)	156	Canada, 92%.
Decolorizing earths and fuller's earth	(2)	48	2	286	China, 80%; Germany, 20%.
Bentonite	9	3,360	10	3,550	Canada, 37%; Greece, 35%; Mexico, 18%.
Common blue clay and other ball clay	1	218	1	261	United Kingdom, 96%.
Other clay	5	3,650	7	4,660	France, 42%; Canada, 25%; Germany, 13%; Mexico, 8%.
Chamotte or Dina's Earth	(2)	2	(2)	9	Germany, 100%.
Artificially activated clay and activated earth	25	14,200	16	10,300	Mexico, 61%; Germany, 26%; Canada, 7%.
Total	251	61,800	298	59,400	XX

XX Not applicable.

[1]Data are rounded to no more than three significant digits.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 16
BENTONITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Algeria[4]	21,286	27,178	25,346	30,319	29,029 [5]
Argentina	135,450	120,006	146,845	163,028	160,000 [5]
Armenia[e]	1,000	258 [5]	642	561	732 [5]
Australia[e, 4]	180,000	200,000	200,000	200,000	200,000
Bolivia	159	216	227	548	550
Bosnia and Herzegovina	5 [e]	9,829	13,050	16,500 [e]	17,000
Brazil, beneficiated	178,610	184,909	198,981 [r]	226,874 [r]	226,900 [5]
Bulgaria	320,000 [e]	212,000	146,000	150,000 [e]	150,000
Burma	634 [r]	600 [r]	600 [r]	500 [r]	500
Chile	1,695	632	748	101 [r]	--
Commonwealth of Indepedent States[e, 6]	750,000	750,000	750,000	750,000	750,000
Croatia	10,580	12,102	13,568	13,500 [e]	13,000
Cyprus	126,600	128,400	144,859	155,717 [r]	150,000
Czech Republic	224,000 [e]	174,000	199,000 [r, e]	201,000 [r]	200,000
Egypt[e]	50,000	50,000	50,000	50,000	50,000
Georgia[e]	7,000	7,000	9,700	1,800 [5]	1,800 [5]
Germany	447,913 [r]	495,310 [r]	478,796 [r]	404,549 [r]	410,000 [5]
Greece[e]	950,000	950,000	950,000	950,000	950,000
Guatemala	3,000 [e]	4,436	6,438	81,688 [r]	135,451 [5]
Hungary	5,200 [e]	3,700	87,290 [r]	87,300 [r]	85,000
Indonesia[e]	5,000	5,000	5,000	5,000	5,000
Iran[7]	113,299 [r]	125,510 [r]	140,528 [r]	193,046 [r]	200,000
Italy[e]	500,000	500,000	500,000	500,000	500,000
Japan	405,738	437,772 [r]	425,945	455,282 [r]	450,000
Kenya[e]	50 [5]	50	50	50	50
Macedonia[e]	30,000	25,000	25,000	25,000	25,000
Mexico	415,133	488,215	464,056	564,015 [r]	425,630 [5]
Morocco	71,741	58,754	67,700 [r]	85,400 [r]	85,400
Mozambique	1,357	--	--	3,336	-- [5]
New Zealand, processed[e]	10,000	7,800	7,800 [5]	7,800	7,800

See footnotes at end of table.

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TABLE 16—Continued
BENTONITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Nicaragua[e]	6,000	6,000	6,300	6,300	6,300
Pakistan	27,000 [e]	28,000	28,000 [e]	6,316 [r]	15,671 [5]
Peru	18,217	20,760	14,980 [r]	18,471	18,500 [p]
Philippines	5,128	5,500	5,000 [e]	5,000 [e]	5,000
Poland[8]	29,000	26,200	31,648 [r]	66,143 [r]	65,000
Romania	24,779	15,389	17,637	18,161 [r]	18,000
Serbia and Montenegro[e]	75	75 [5]	75	75	75
Slovakia	82,915	66,128	74,938	73,273 [r]	70,000
South Africa[9]	108,300 [r]	101,100 [r]	145,060	55,859	139,833 [5]
Spain[e]	150,000	150,000	150,000	150,000	150,000
Turkey	674,178 [r]	559,224	831,146	850,000 [e]	925,000
Turkmenistan[e]	50,000	50,000	50,000	50,000	50,000
Ukraine[e]	300,000	300,000	300,000	300,000	300,000
United States	3,970,000	3,970,000	3,770,000 [r]	4,550,000 [r]	4,710,000 [5]
Zimbabwe[9]	2,247 [r]	3,780 [r]	-- [e]	500 [r, e]	500
Total	10,400,000	10,300,000	10,500,000 [r]	11,500,000 [r]	11,700,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through August 21, 2006.

[3]In addition to the countries listed, Canada and China are thought to produce bentonite, but output is not reported, and available information is inadequate to make reliable estimates of output levels.

[4]Includes bentonitic clays.

[5]Reported figure.

[6]Information is inadequate to formulate reliable estimates for individual countries, except Armenia, Georgia, Turkmenistan, and Ukraine.

[7]Year beginning March 21 of that stated.

[8]Montmorillite type bleaching clay.

[9]May include other clays.

TABLE 17
FULLER'S EARTH: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Algeria	3,254	3,521	2,573	2,284	831 [4]
Argentina[e]	1,500	1,500	1,500	1,500	1,500
Australia, attapulgite	5,600	6,000	6,000 [e]	6,000 [e]	6,000
Germany, unprocessed[e]	500,000	500,000	500,000	500,000	500,000
Israel	--	998,193	892,658	850,000	850,000
Italy[e]	30,000	30,000	30,000	30,000	30,000
Mexico	148,194	147,064	152,917	129,502 [r]	107,265 [4]
Morocco, smectite	40,664	43,243	14,944	15,000 [e]	15,000
Pakistan[e]	15,000	15,000 [4]	15,000	15,000	15,000
Senegal, attapulgite	121,200	138,400	194,900	200,000 [r, e]	200,000
South Africa, attapulgite	9,229	13,288 [r]	14,585 [r]	20,419	34,241 [4]
Spain:					
Attapulgite	24,477	22,918	18,975	19,000 [e]	20,000
Sepiolite	673,600	733,134	690,395	700,000 [e]	700,000
United Kingdom[e, 5]	140,000	140,000	140,000	140,000	140,000
United States[6]	2,890,000	2,730,000	3,600,000	3,260,000	2,990,000 [4, 7]
Total	4,600,000	5,520,000	6,280,000 [r]	5,890,000 [r]	5,610,000

See footnotes at end of table.

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TABLE 17—Continued
FULLER'S EARTH: WORLD PRODUCTION, BY COUNTRY[1, 2]

[e]Estimated. [r]Revised. -- Zero.
[1]Excludes centrally planned economy countries and former such countries, some of which presumably produce fuller's earth but for which no information is available. Table includes data available through August 21, 2006.
[2]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[3]In addition to the market economy countries listed, France, India, Iran, Japan, and Turkey have reportedly produced fuller's earth in the past and may continue to do so, but output is not reported, and available information is inadequate to make reliable estimates of output levels.
[4]Reported figure.
[5]Salable product.
[6]Sold or used by producers.
[7]Includes only montmorillonite-type fuller's earth; sales use of attapulgite-type fuller's earth was withheld to avoid disclosing company proprietary data.

TABLE 18
KAOLIN: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Algeria	13,356	9,505	16,591	24,299	34,386 [4]
Argentina	13,584	13,865	19,219	27,883	30,000
Australia, includes ball clay[e]	220,000	230,000	230,000	230,000	230,000
Austria, marketable[e]	50,000	50,000	50,000	50,000	50,000
Bangladesh[e, 5]	8,000	8,100	8,200	8,300	8,400
Belgium[e]	300,000	300,000	300,000	300,000	300,000
Bosnia and Herzegovina, crude	13,000	6,500	--	--	--
Brazil, beneficiated	1,734,359	1,757,488	2,081,039	2,197,920 [r]	2,198,000 [p, 4]
Bulgaria	150,000	160,000	170,000	180,000 [r]	150,000
Chile	5,300	6,164	11,500	7,133 [r]	15,183 [4]
Colombia, includes common clay[e]	8,500,000	8,500,000	8,500,000	8,500,000	8,500,000
Czech Republic	5,543,000	3,650,000	4,155,000	3,862,000 [r]	4,000,000
Denmark, sales[e]	2,500	2,500	2,500	2,500	2,500
Ecuador	703	8,483	11,883 [r]	5,646 [r]	5,928 [p, 4]
Egypt[e]	300,000	300,000 [4]	300,000	300,000	300,000
Eritrea	588	250	281 [r]	101 [r]	100
Ethiopia	1,800 [e]	3,534	3,088	4,251 [r]	4,300
France, marketable[e]	300,000	300,000 [4]	300,000	300,000	300,000
Germany	3,763,798 [r]	3,666,405 [r]	3,467,435 [r]	3,752,000	3,750,000
Greece[e]	60,000	60,000 [4]	60,000	60,000	60,000
Guatemala	227	372	1,497	-- [r]	4,107 [4]
Hungary, processed[e]	8,000	4,300	13,250 [r, 4]	13,300 [r, 4]	13,000
India:[e]					
Processed	170,000	170,000 [4]	180,000	180,000	190,000
Salable crude	540,000	540,000 [4]	550,000	550,000	560,000
Indonesia[e]	15,000	15,000 [4]	15,000	15,000	15,000
Iran	635,888 [r]	553,782 [r]	484,507 [r]	531,109 [r]	500,000
Italy, kaolinitic earth[e]	10,000	10,000	10,000	10,000	10,000
Japan	17,240 [r]	11,756	12,409	11,553 [r]	115,000
Jordan	24,124 [r]	100,000 [r, e]	179,153	216,566	220,000 [4]
Kazakhstan[e]	70,000	70,000	70,000	70,000	70,000
Kenya	700	710 [r]	730 [r]	750 [r]	750
Korea, Republic of	2,306,083 [r]	2,727,481 [r]	3,009,245 [r]	2,780,020 [r]	2,767,091 [4]
Kyrgyzstan[e]	200,000	237,100 [4]	381,100 [4]	400,000	400,000
Madagascar[e]	170	170 [r]	170	170	170
Malaysia	364,458	323,916	425,942 [r]	326,928 [r]	350,000
Mexico	681,709	745,498	798,407	654,711 [r]	877,147 [4]

See footnotes at end of table.

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TABLE 18—Continued
KAOLIN: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
New Zealand	15,000	16,000	16,000 [e]	16,000 [e]	16,000
Nigeria[e]	209,478 [4]	200,000	200,000	210,000	210,000
Pakistan[e]	50,000	50,000	50,000	25,204 [r, 4]	37,732 [4]
Paraguay[e]	66,500 [r]	66,700 [r]	66,600 [r]	66,600 [r]	66,600
Peru	5,532	1,934	2,653	2,720	2,720 [4]
Poland, washed	101,200	113,500	169,034 [r]	191,312 [r]	190,000
Portugal[e]	175,000	175,000	175,000	175,000	175,000
Romania	21,867	22,514	25,741 [r]	22,337 [r]	22,000
Russia, concentrate[e]	45,000	45,000 [4]	45,000	45,000	45,000
Serbia and Montenegro:					
Crude	60,900	60,000	60,000 [e]	60,000 [e]	60,000
Washed[e]	10,000	10,000	10,000	10,000	10,000
Slovakia	35,000	33,000	24,800 [r]	89,424 [r]	85,000
South Africa	85,556	86,700 [r]	86,365 [r]	81,901	60,072 [4]
Spain, marketable, crude and washed[e, 6]	350,000	350,000	350,000	350,000	350,000
Sri Lanka	9,403	8,613	9,073	9,200 [e]	9,400
Thailand, beneficiated	168,063	127,132	184,562	200,761 [r]	201,000
Turkey	574,550	372,344	370,455	536,008 [r]	580,000
Uganda	90	178	-- [r]	537 [r]	31,000
Ukraine[e]	225,000	225,000 [4]	225,000	225,000	225,000
United Kingdom, sales[e, 7]	2,400,000	2,400,000 [4]	2,400,000	2,400,000	2,400,000
United States[8]	8,110,000	8,010,000	7,680,000	7,760,000	7,800,000 [4]
Uzbekistan[e]	5,500,000	5,500,000	5,500,000	5,500,000	5,500,000
Venezuela[e]	10,000	10,000	10,000	10,000	10,000
Vietnam[e]	600,000	600,000	650,000	650,000	650,000
Zambia[e]	200	200	200	200	200
Total	44,900,000 [r]	43,000,000 [r]	44,100,000 [r]	44,200,000 [r]	44,700,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through August 21, 2006.

[3]In addition to the countries listed, China, Morocco, and Suriname may also have produced kaolin, but information is inadequate to make reliable estimates of output levels.

[4]Reported figure.

[5]Data for year ending June 30 of that stated.

[6]Includes crude and washed kaolin and refractory clays not further described.

[7]Dry weight.

[8]Kaolin sold or used by producers.

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COBALT

By Kim B. Shedd

Domestic survey data and tables were prepared by Jo-Ann S. Sterling, statistical assistant, and the world production tables were prepared by Linder Roberts, international data coordinator.

In 2005, world production of refined cobalt increased, primarily as a result of a significant increase in production from China. The United States did not mine or refine cobalt in 2005. However, a small number of mining operations produced negligible amounts of byproduct cobalt as intermediate products. Since 1993, sales of excess cobalt from the National Defense Stockpile (NDS) have contributed to U.S. and world supplies.

World demand for cobalt increased as a result of an increase in cobalt demand from the aerospace and land-based gas turbine industries and growth of cobalt use in rechargeable batteries and catalysts. U.S. apparent consumption of cobalt was greater than that of 2004. The overall trend in cobalt prices was downward, signifying that the supply of cobalt was more than sufficient to meet demand (Inco Ltd., 2006b, p. 18; Searle, 2006; Cobalt Development Institute and World Bureau of Metal Statistics, undated§[1]).

Salient U.S. and world cobalt statistics for 2005 and the previous 4 years are listed in table 1. With the exception of prices and reported production from foreign countries, all quantity and value data in this report have been rounded to no more than three significant digits. Totals and percentages were calculated from unrounded numbers.

Cobalt is a strategic and critical metal used in many diverse commercial, industrial, and military applications. Historically, the leading use of cobalt has been in superalloys, which are used to make parts for gas turbine engines. In recent years, rapid growth in the rechargeable battery industry has resulted in a significant increase in the use of cobalt to make battery electrodes, such that now, on a global basis, the battery and superalloy industries consume similar amounts of cobalt. Cobalt is also used to make airbags in automobiles; catalysts for the petroleum and chemical industries; cemented carbides (also called hardmetals) and diamond tools; corrosion- and wear-resistant alloys; drying agents for paints, varnishes, and inks; dyes and pigments; ground coats for porcelain enamels; high-speed steels; magnetic recording media; magnets; and steel-belted radial tires.

Legislation and Government Programs

During fiscal year 2005 (October 1, 2004, through September 30, 2005), the Defense National Stockpile Center (DNSC), U.S. Department of Defense, periodically offered cobalt under a basic ordering agreement (BOA). Cobalt was awarded each month except October and November. The DNSC sold 1,120 metric tons (t) of cobalt cathode, granules, and rondelles valued at $37 million (table 2). This represented 41% of the 2,720-t (6-million-pound) maximum allowed for sale under the fiscal year 2005 Annual Materials Plan (AMP). As of the end of the fiscal year, 239 t of cobalt had been sold but not shipped from the stockpile. The AMP for fiscal year 2006 (October 1, 2005, through September 30, 2006) maintained the maximum allowable sale of cobalt at 2,720 t (U.S. Department of Defense, 2006, p. 5, 8, 12, 56, 62).

During calendar year 2005, the DNSC made BOA awards each month except December. During this period, the DNSC sold 880 t of cobalt valued at $26.9 million. On December 31, the total uncommitted cobalt inventory held by the DNSC was 1,480 t of cobalt cathode. Although the DNSC had authority to sell the remaining cobalt inventory, the agency suspended sales in December until it determined whether the cobalt was needed by the military (Platts Metals Week, 2006).

The Public Health Service released the 11th edition of the "Report on Carcinogens," a document that lists all substances that are either known to be human carcinogens or may reasonably be anticipated to be human carcinogens and to which a significant number of persons residing in the United States are exposed. Cobalt sulfate was listed as reasonably anticipated to be a human carcinogen based on sufficient evidence of carcinogenicity in experimental animals (Public Health Service, 2005, 2005§).

Production

With the exception of negligible amounts of byproduct cobalt produced from lead, platinum-group metal (PGM), and zinc operations, the United States did not mine or refine cobalt in 2005. Cobalt-bearing nickel sulfate produced from Stillwater Mining Co.'s PGM mining and refining operations in southeastern Montana was sold to several companies. Some of southeastern Missouri's lead ores contained minor amounts of cobalt. Big River Zinc Corp.'s refinery in Sauget, IL, recovered cobalt from zinc sulfide concentrates mined in southeastern Missouri, Tennessee, and overseas. Zinc refining operations at Sauget were scheduled to cease in early 2006 (Korea Zinc Co., Ltd., 2006, p. 6; Big River Zinc Corp., undated a§, b§).

In 2005, there were three U.S. mine projects in the feasibility and permitting stages of development that planned to produce cobalt—Formation Capital Corp.'s Idaho cobalt project, PolyMet Mining Corp.'s NorthMet project, and Kennecott Minerals Co.'s Eagle project.

Formation planned to develop an underground cobalt-copper-gold mine and mill complex in the Idaho Cobalt Belt in Lemhi County, ID, and retrofit its hydrometallurgical refinery in Big Creek, ID, to refine the cobalt concentrates produced. The retrofitted refinery was to have the capacity to produce approximately 1,500 metric tons per year (t/yr) of cobalt as cathode and/or cobalt compounds. Formation expected to the receive final permits for the mine during the last quarter of 2006 or the first quarter of 2007 and hoped to complete mine construction and begin production approximately 1 year after receiving the permits (Formation Capital Corp., 2004, p. 10; 2006, p. 2).

[1]References that include a section mark (§) are found in the Internet References Cited section.

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PolyMet planned to mine the NorthMet polymetallic deposit in the Duluth Complex of northeastern Minnesota by open pit methods. Ore would be treated at the nearby Cliffs-Erie mill and concentrator to produce a bulk concentrate, which would be processed in a new hydrometallurgical plant using the company's PlatSol technology. PolyMet would produce copper cathode, either a nickel-cobalt-zinc hydroxide or cobalt, nickel, and zinc hydroxides, and a precipitate of PGMs and gold. At a production rate of 25,000 metric tons per day of ore, approximately 375 t/yr of cobalt could be produced. PolyMet hoped to begin commercial production in mid 2008 (PolyMet Mining Corp., 2005, p. 20; 2006, p. 8, 13; Dreisinger and others, 2006, p. 18-19).

Kennecott planned to develop a small underground nickel-copper mine in the Eagle deposit in the Yellow Dog Plains area northwest of Marquette, MI. The company would crush ore at the mine site and then send the crushed ore to an offsite processor. The Eagle deposit was a high-grade magmatic sulfide with indicated and inferred resources totaling 4 million metric tons (Mt) grading 3.57% nickel, 2.91% copper, 0.10% cobalt, and 0.28 grams per metric ton (g/t) gold (Foth & Van Dyke and Associates, Inc., 2006, p. 1, 17).

U.S. processors made cobalt chemicals and cobalt metal powders from refined cobalt materials and/or cobalt-bearing scrap. U.S. Geological Survey (USGS) data on chemical and metal powder production, shipments, and stocks were derived from a monthly voluntary survey of U.S. cobalt processors. Information from this survey was used to prepare the statistics on cobalt consumption and stocks in table 3. Five of the seven cobalt processors on this survey provided data. Estimates were made for plants for which data were not provided. Two processors made extra-fine cobalt metal powder in the United States. Carolmet Cobalt Products (a division of n.v. Umicore s.a.) made cobalt metal powder from cobalt metal at its Laurinburg, NC, plant. Osram Sylvania Inc. produced cobalt metal powder as a byproduct of tungsten recovered from cemented carbide scrap in Towanda, PA. Production and shipments of cobalt metal powder are withheld to avoid disclosing company proprietary data. In 2005, Umicore set up a new recycling unit at its facility in Arab, AL (n.v. Umicore, s.a., 2006, p. 4).

Consumption

U.S. apparent consumption for 2005, as calculated from net imports, consumption from purchased scrap, and changes in Government and industry stocks, was 20% greater than that calculated for 2004 (table 1). The increase in consumption was met primarily by an increase in imports.

U.S. reported consumption of cobalt in 2005 was approximately equal to that of 2004. Compared with 2004, metallurgical industries consumed 3% more cobalt, and the cobalt consumption for chemical uses was 8% lower. Reported consumption was derived by the USGS from voluntary surveys of U.S. operations. Most of the data on cobalt chemical uses were obtained from the cobalt processors survey. A second survey covered a broad range of metal-consuming companies, such as cemented carbide, magnetic alloy, and superalloy producers. For this survey, nearly 70 cobalt consumers were canvassed on a monthly or annual basis. Reported consumption and stocks data in tables 1 and 3 contain estimates to account for nonrespondents.

Prices

U.S. spot price ranges for cathode (minimum of 99.8% cobalt), as reported by Platts Metals Week, generally trended downward during the year. The highest price, at a range of $19.25 to $19.75 per pound, was reported in mid-January, and the lowest price, at a range of $12.05 to $13.30 per pound, was reported in early November. The annual average U.S. spot cathode price for 2005 was $15.96 per pound, down by 33% from that of 2004 (table 1). Trends in Platts' prices for Zambian cobalt (minimum 99.6% cobalt) and Russian cobalt (minimum 99.3% cobalt) were similar to those for U.S. spot cathode. The annual average of weekly prices for Zambian cobalt was $15.06 per pound, and the annual average of weekly prices for Russian cobalt was $14.62. Sales prices for 99.8% cobalt cathode reported by BHP Billiton ranged from $12.10 to $19.25 per pound.

Foreign Trade

Net import reliance as a percentage of apparent consumption is used to measure the adequacy of current domestic production to meet U.S. demand. Net import reliance was defined as imports minus exports plus adjustments for Government and industry stock changes. Releases from stocks, including shipments from the NDS, were counted as part of import reliance, regardless of whether they were imported or produced in the United States. In 2005, net import reliance as a percentage of apparent consumption was 83%. Because there was no measurable U.S. primary cobalt production in 2005, this indicates that 83% of U.S. cobalt supply was from imports and stock releases of primary cobalt and 17% was from scrap, which would have been generated domestically or imported.

The following discussion of cobalt imports is based on cobalt contained in metal, including metal powder, and chemicals. In 2005, the United States imported 27% more cobalt than it did in 2004 (tables 4, 5). Ten countries supplied 91% of U.S. imports. Norway was the leading supplier, followed by Russia, Finland, China, Zambia, Canada, Belgium, Morocco, Australia, and Brazil. Compared with those of 2004, cobalt imports from Brazil, China, Finland, Morocco, Norway, Russia, and Zambia increased, and imports from Australia, Belgium, and Canada decreased.

In 2005, the United States imported 101 t, gross weight, of unwrought cobalt alloys valued at $2.7 million. Five countries supplied most of these materials—Norway (39%), the United Kingdom (38%), Japan (13%), China (5%), and Germany (3%). The United States imported 815 t, gross weight, of cobalt waste and scrap valued at $7.9 million. Eight countries supplied most of this material—the United Kingdom (20%), Canada and Ireland (17% each), France (13%), Germany (11%), India (7%), and Austria and Japan (6% each). The United States also imported 256 t, gross weight, of wrought cobalt and cobalt articles valued at $17.7 million. The leading suppliers of these materials were the United Kingdom (59%), Japan (10%), Canada (9%), Germany (8%), and Australia and France (6% each).

U.S. exports of unwrought cobalt and cobalt contained in chemicals decreased by 3% compared with those of 2004. As listed in table 6, more than 90% of the cobalt metal and chemical exports was shipped to nine countries—Belgium,

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Canada, France, Germany, Ireland, Japan, Mexico, Singapore, and the United Kingdom. The remainder was shipped to 39 other countries.

Exports also included 2,340 t, gross weight, of wrought metal and cobalt articles valued at $91.8 million. More than 90% of these materials was sent to 9 countries—the United Kingdom (26%), Belgium (24%), France (15%), Japan (9%), Germany (8%), Ireland (3%), and Canada, the Republic of Korea, and Switzerland (2% each). The remainder was shipped to 48 other countries.

World Industry Structure

Historically, most of the world's cobalt was produced as a byproduct of copper, nickel, or other metals. Until recently, Morocco was identified as the only country where cobalt was produced as the principal (primary) product of a mining operation. The artisanal mining of the cobalt mineral heterogenite in Congo (Kinshasa), which has increased since the late 1990s, should be considered primary cobalt production. The recovery of cobalt from previously stockpiled intermediate materials (for example, slags) could be classified either as primary production, in that the materials are processed primarily to recover the cobalt, or as byproduct production, because the materials were originally produced as a byproduct of copper mining and refining. Thus, the percentage of cobalt produced as a primary product will depend on how the production is categorized, but may have represented more than one-half of world cobalt production in 2005 (Cobalt Development Institute, 2006a; Searle, 2006).

Refinery capacity by country is listed in table 7. Plants that processed refined cobalt, that used secondary materials (scrap) as their main source of feed, or that produced a cobalt product that required further refining were not included.

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Australia.—QNI Pty. Ltd. (a subsidiary of BHP Billiton) processed lateritic ore imported from Indonesia, New Caledonia, and the Philippines at its Yabulu nickel-cobalt refinery in Townsville, Queensland, and produced 1,400 t of cobalt as cobalt oxide hydroxide, 26% less than the 1,900 t produced in 2004. During the year, the company worked on building a nickel-cobalt laterite mine and front-end acid leaching plant at Ravensthorpe on the southern coast of Western Australia and expanding the Yabulu refinery to accommodate the intermediate material produced from Ravensthorpe. The expanded refinery was to have the capacity to produce 76,000 t/yr of nickel and 3,500 t/yr of cobalt. It would continue to process imported lateritic ore, but Ravensthorpe was to supply as much as 50,000 t/yr of nickel and 1,400 t/yr of cobalt in nickel-cobalt mixed hydroxide. The first shipment of mixed hydroxide was scheduled for the second quarter of 2007, and the first nickel metal production from the expanded Yabulu refinery was scheduled for the third quarter of 2007 (Cobalt Development Institute, 2006c; BHP Billiton, 2006, 2004§).

In August, BHP Billiton acquired WMC Resources Ltd. and renamed the former WMC nickel producing assets Nickel West. Nickel West produced cobalt in intermediate nickel-cobalt mixed sulfide at its Kwinana nickel refinery in Western Australia. The refinery processed matte from Nickel West's Kalgoorlie smelter, which was produced from nickel sulfide concentrates from ores mined in Western Australia by Nickel West and other companies. Nickel West's mixed sulfide was refined in Norway by Falconbridge Ltd. under a tolling agreement, and the resulting cobalt cathode was offered for sale by WMC Resources Marketing Ltd. on BHP Billiton's Web site. Nickel West also sold nickel concentrates and matte (BHP Billiton, undated§).

Minara Resources Ltd. produced 1,750 t of cobalt as metal powder and briquettes from its Murrin Murrin nickel-cobalt laterite pressure-acid leaching operation east of Leonora in Western Australia, 12% less than the 1,979 t produced in 2004. Production was impacted by a planned 3-week plant-wide shutdown, delays in restarting the hydrogen sulfide plant after planned shutdowns, and a failure in the acid plant. While continuing to work on improving plant performance at Murrin Murrin, Minara decided to build a demonstration plant to recover nickel and cobalt by heap leaching stockpiled ore reject material. The plant's capacity was to be 2,000 t/yr of nickel and 120 t/yr of cobalt (Cobalt Development Institute, 2006c; Minara Resources Ltd., 2006, p. 6-7, 27).

OM Group, Inc. (OMG) shipped intermediate nickel hydroxide produced from its Cawse plant, northwest of Kalgoorlie in Western Australia, to Finland for refining. Output from the plant, which used pressure acid leaching to treat lateritic ore, was expected to supply approximately 8,000 t/yr of nickel to Harjavalta and 800 t/yr of cobalt to Kokkola (OM Group, Inc., 2001; Reuters Ltd., 2002).

Sally Malay Mining Ltd. mined nickel sulfide ores in the East Kimberly District of Western Australia and produced concentrates containing 426 t of cobalt. The concentrates were shipped to Jinchuan Group Ltd. under a life-of-mine sales agreement (Sally Malay Mining Ltd., 2005a, b).

Fox Resources Ltd. mined nickel sulfide ores from the Radio Hill Mine near Karratha in Western Australia and shipped concentrates to Jinchuan Group Ltd.'s operations in Gansu Province, China. Fox studied the feasibility of using the BioHeap bacterial oxidation heap-leaching process to treat disseminated nickel sulfide ores from Radio Hill and the nearby Sholl nickel sulfide deposit (Fox Resources Ltd., 2005, p. 9, 19).

In addition to the production discussed above, cobalt-bearing nickel sulfide concentrates produced from several operations in Australia were exported to Inco Ltd. in Canada, as discussed in the "Canada" portion of the "World Review" section of this report. WMC's contract to supply nickel sulfide concentrates from its Mt. Keith operations to OMG in Finland expired in March (WMC Resources Ltd., 2005, p. 28).

Zinifex Ltd. shipped zinc concentrates produced at its Century Mine in northern Queensland to the Budel smelter in the Netherlands, where approximately 25 t of cobalt was recovered as filter cake (Bowyer, 2003).

Allegiance Mining NL completed a feasibility study on an underground mine and concentrator at its Avebury nickel project in western Tasmania. Allegiance planned to begin production in 2007 at an initial rate of 28,800 t/yr of nickel sulfide concentrates grading more than 20% nickel and 0.4% cobalt. At yearend, Allegiance was in the final stages of negotiation with a potential partner that would provide financial and technical support and buy the concentrates (Allegiance Mining NL, 2006, p. 6, 11).

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Compass Resources NL purchased the solvent extraction plant and much of the electrowinning plant that had been installed at the Cawse nickel laterite operation in Western Australia. These purchases allowed the company to decide to fast-track develop its Browns Oxide project in the Northern Territory, subject to final permits and funding. The company planned to use agitated sulfuric acid leaching followed by solvent extraction-electowinning (SX-EW) to produce 10,000 t/yr of copper cathode, 1,000 t/yr of cobalt as a chemical precipitate, and 700 t/yr of nickel as a chemical precipitate (Compass Resources NL, 2005, 2006).

LionOre Mining International Ltd. studied the feasibility of converting the company's Avalon plant to treat nickel sulfide ores from the Honeymoon Well deposit in Western Australia by using the company's Activox hydrometallurgical process (LionOre Mining International Ltd., 2006, p. 9).

Gladstone Pacific Nickel Ltd. studied the feasibility of developing a nickel laterite mine at Marlborough and a high-pressure acid-leach refinery at the deepwater port city of Gladstone in Queensland. The company was considering developing the project in three stages. Stage I would produce approximately 30,000 t/yr of nickel metal briquettes and 1,400 t/yr of cobalt metal briquettes solely from Marlborough ore. Stage II production (60,000 t/yr of nickel and 3,800 t/yr of cobalt) would be supplemented by high-grade nickel laterite ore imported from the southwest Pacific region (Indonesia, New Caledonia, Papua New Guinea, the Philippines, and Solomon Islands). Stage III production (124,000 t/yr of nickel and 9,900 t/yr of cobalt) would be primarily from imported ore. Gladstone hoped to have the construction for stage I completed in 2009 (Gladstone Pacific Nickel Ltd., 2005§).

Sherlock Bay Nickel Corp. Ltd. reviewed a 2004 bankable feasibility study on developing the low-grade disseminated nickel sulfide ores from the Discovery and Symonds nickel sulfide deposits in Western Australia. The company determined that additional work was necessary to update the study, which evaluated the use of BioHeap bacterial leaching to produce approximately 8,500 t/yr of nickel, 1,200 t/yr of copper, and 100 t/yr of cobalt (Sherlock Bay Nickel Corp. Ltd., 2004, p. 9-13; 2005).

In mid-2004, Ivanplats Syerston Pty. Ltd. acquired the Syerston nickel-cobalt laterite project near Fifield in New South Wales from Black Range Minerals Ltd. Ivanplats proposed several modifications to the project, including an increase in the ore processing rate and the removal of the metals refinery from the processing plant. As modified, the project would produce 53,000 t/yr of nickel-cobalt mixed sulfide (New South Wales Government, 2005§).

Belgium.—Umicore converted cobalt metal, residues, and other cobalt-bearing materials into a wide range of cobalt specialty products, including metal powders, oxides, salts, and compounds. According to the Cobalt Development Institute (2006c), Umicore's 2005 cobalt refinery production was 3,298 t, 12% more than the 2,947 t produced in 2004. This production took place in plants in Olen, Belgium; south-central China; and Roodepoort, South Africa. In addition, Umicore produced specialty cobalt products at processing plants in Arab, AL, and Laurinburg, NC, in the United States; Leduc and Fort Saskatchewan, Alberta, Canada; Guangzhou and Shanghai, China; Subic, Philippines; and Cheonan, Republic of Korea.

Botswana.—LionOre decided to commercialize its Activox hydrometallurgical process by developing projects at the Honeymoon Well deposit in Australia, the Nkomati joint venture in South Africa, and the Tati Nickel Mining Co. (Proprietary) Ltd. operation in Botswana. The first full-scale Activox refinery was to be built at Tati. LionOre planned to complete a feasibility study by the end of June 2006, so that it could begin construction in 2007 and commercial production in 2009. The refinery would produce an estimated 25,000 t/yr of nickel cathode as well as copper cathode and cobalt carbonate (LionOre Mining International Ltd., 2006, p. 8-12).

Brazil.—Cia. Niquel Tocantins (CNT) produced cobalt cathode at its refinery in Sao Miguel Paulista, Sao Paulo State, from lateritic nickel-cobalt ore mined from Niquelandia, Goias State. CNT has gradually expanded the refinery's capacity during the past few years.

Companhia Vale do Rio Doce (CVRD) approved the investment to develop the Niquel do Vermelho laterite deposits in the Carajas region of Para State. CVRD planned to build a high-pressure acid leaching plant with the capacity to produce 46,000 t/yr of nickel cathode and 2,800 t/yr of cobalt cathode. The project was expected to have a commercial life of 40 years, with production beginning in late 2008 (Companhia Vale do Rio Doce, 2005).

Canada.—Falconbridge produced 525 t of cobalt in concentrate from its Sudbury, Ontario, mines and 354 t of cobalt in concentrate from its Raglan Mine in Quebec. Nickel-copper matte produced at the Sudbury smelter was refined at the company's Nikkelverk refinery in Norway. In 2005, this matte contained 2,423 t of cobalt; 36% of the cobalt originated from ores produced at company mines, and 64% from custom feed materials, defined as feeds that did not originate from Falconbridge mines. The custom feed was primarily nickel-copper-cobalt secondary materials (scrap) and nickel concentrates. Some of the concentrates originated from nickel sulfide ores mined in Ontario by Canadian Arrow Mines Ltd. and First Nickel Inc. Falconbridge also processed some palladium concentrates containing minor amounts of cobalt from North American Palladium Ltd.'s Lac des Iles Mine in northern Ontario (Falconbridge Ltd., 2006, p. 22, 49-51).

According to the Cobalt Development Institute (2006c), Inco produced 1,563 t of cobalt in 2005, essentially the same amount as it produced in 2004. Approximately 85% of Inco's production was cathode from the company's Port Colborne, Ontario, refinery, and 15% was oxide from its Thompson, Manitoba, refinery. The cobalt originated from nickel sulfide ores from company mines at Sudbury (57%); nickel sulfide ores from company mines in Manitoba (19%); and purchased feedstocks (24%), including nickel sulfide ore from FNX Mining Co. Inc.'s Sudbury operations, nickel sulfide concentrates from Jubilee Mines NL's Cosmos nickel project and LionOre's Emily Ann Mine in Western Australia, and palladium concentrates from North American Palladium. In preparation for treating concentrates from Voisey's Bay, Inco worked on a project to double the cobalt capacity of its Thompson refinery (Inco Ltd., 2006a, p. 11, 24; 2006b, p. 18, 20, 56).

Inco completed construction of its Voisey's Bay nickel-copper-cobalt-sulfide mine and concentrator in northeastern Labrador and began commercial production. Shipments of nickel concentrates to Inco's Ontario and Manitoba operations began in November. The company expected to produce approximately 1,100 t of cobalt from Voisey's Bay nickel concentrates in 2006. When fully operational, production from Voisey's Bay was expected to

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be 50,000 t/yr of nickel in concentrates containing 7,000 t/yr of copper and 2,300 t/yr of cobalt as well as 32,000 t/yr of copper in concentrates. In October, Inco completed construction and began operating a demonstration plant in Argentia, Newfoundland. The demonstration plant was for testing hydrometallurgical processes on Voisey's Bay concentrates. Inco planned to build and begin operating a commercial processing facility in the Province by the end of 2011. Once the commercial facility was operational, it would treat all of the concentrates from Voisey's Bay and produce finished nickel and cobalt products by using hydrometallurgical processing technologies, or if hydrometallurgical processing did not prove to be technically or economically feasible, by using conventional technologies (Inco Ltd., 2006b, p. 18, 48).

The Fort Saskatchewan refinery of the joint venture of Sherritt International Corp. and General Nickel Co. S.A. produced 3,391 t of cobalt as metal powder and briquettes in 2005, slightly more than the 3,325 t produced in 2004. Eighty-nine percent of the cobalt was from nickel-cobalt sulfides from the joint venture's operations at Moa Bay, Cuba; the remainder was from feed materials purchased from four suppliers. Sherritt and General Nickel agreed to expand their nickel-cobalt operations in Canada and Cuba. Construction at Fort Saskatchewan was to begin during the third quarter of 2006 so that commissioning could begin by the third quarter of 2008. As a result of a United States embargo on imports of products originating from Cuba, cobalt and nickel produced by Sherritt cannot be sold to customers in the United States (Sherritt International Corp., 2006, p. 3, 23, 26-27).

FNX produced nickel sulfide ore from its McCreedy West Mine containing 45 t of cobalt, compared with 36 t in 2004. The ore was processed by Inco (FNX Mining Co. Inc., 2006).

Fortune Minerals Ltd. studied the feasibility of developing the NICO gold-cobalt-bismuth deposit, 160 kilometers (km) northwest of Yellowknife in the Northwest Territories. Fortune was considering mining the deposit by open pit and underground methods and then producing gold-bismuth and gold-cobalt sulfide concentrates by mineral flotation. The gold-cobalt concentrate would be processed onsite by a hydrometallurgical process; 1,200 to 1,500 t/yr of cobalt cathode would be produced by SX-EW. During the year, Fortune conducted mini-pilot-plant tests of the proposed process and entered into an agreement to purchase the mill from Newmont Canada Ltd.'s Golden Giant Mine. Fortune planned to move the mill from its location at Hemlo, Ontario, and use it for processing the ores from the NICO deposit (Fortune Minerals Ltd., 2005; 2006, p. 4, 14).

Blue Earth Refineries Inc. held a 49.2% interest in 36569 Yukon Inc., which owned the cobalt refinery in Lorrain Township, Ontario, previously owned by Canmine Resources Corp. During the year, Blue Earth determined that the availability of cobalt feedstock for the refinery was very limited. As a result, the company was considering the following options for the refinery: using it to participate in the future gas-to-liquid catalyst market, dismantling and relocating it to South Africa where it would be closer to a supply of cobalt feedstock, using it to recover metals from waste, or selling it (Blue Earth Refineries Inc., 2005, p. 16-18).

China.—China's production of refined cobalt was estimated to be 15,178 t, which made it the world's leading producer. Only about 10% of China's cobalt production was from domestic mines. The remainder was from imported raw materials, most of which was heterogenite ores from Congo (Kinshasa). One analyst estimated that China imported 15,926 t of cobalt contained in ore and concentrate in 2005; cobalt-bearing matte and scrap were also imported. The cobalt produced was in the form of metal, metal powders, and compounds, and was made for domestic use and export. Since 1998, Chinese cobalt consumption has grown by an average annual rate of 20%. The growth was driven primarily by consumption by the battery industry, which represented more than one-half of Chinese cobalt consumption in 2005 (Aidong, 2006, p. 3, 5, 14-15; Cobalt Development Institute, 2006a; Searle, 2006).

The number of Chinese cobalt refiners and processors was reported to be approximately 50. The leading three refiners were Jinchuan Group Ltd., Ganzhou Yi Hao Umicore Industries, and Zhejiang Huayou Cobalt Nickel Materials Co., Ltd., listed in descending order of 2005 refined cobalt production. Jinchuan reportedly produced 4,500 t of cobalt as cathode and other products in 2005. The company has been steadily increasing its refinery capacity and planned for cobalt production to reach 6,000 t in 2006 and 10,000 t in 2008. Some of Jinchuan's cobalt production was from domestic nickel-copper-cobalt sulfide ores mined and refined at Jinchang, Gansu Province, and some was from other nickel or cobalt feeds. Jinchuan purchased cobalt carbonates produced in China from imported cobalt concentrates and nickel-copper concentrate from GobiMin Inc.'s mines in the Hami region of northwestern China. The company imported nickel-copper concentrates from Fox Resources and Sally Malay in Australia, nickel-copper concentrates from Rio Narcea Gold Mines Ltd. in Spain, and nickel matte from BHP Billiton's Nickel West operations in Australia. During the year, Jinchuan considered investments in the Nonoc nickel plant in the Philippines, the Avebury nickel project in Australia, and a copper-cobalt smelter project in Congo (Kinshasa) (Aidong, 2004, 2006, p. 3; Cobalt Development Institute, 2006a; Ryan's Notes, 2006; Li, 2005§).

Umicore announced plans to double the cobalt refining capacity at its Ganzhou Yi Hao Industries plant in Jiangxi Province. Following this increase, Umicore's combined cobalt refining capacity from plants in Belgium and China would be more than 5,000 t/yr (n.v. Umicore s.a., 2005, p. 4).

Congo (Kinshasa).—According to the Cobalt Development Institute (2006c), La Générale des Carrières et des Mines (Gécamines) produced only 600 t of refined cobalt in 2005. Although its production of refined cobalt has been very low in recent years, Congo (Kinshasa) has continued to supply the world with significant quantities of cobalt in raw and semirefined materials, such as ore concentrates, carbonate, and copper-cobalt alloys. Large quantities of cobalt-rich ores containing the mineral heterogenite have been hand-picked by tens of thousands of artisanal miners, sold to middlemen or trading houses, and exported, primarily to China and India. Some of the heterogenite was processed into cobalt carbonate or cobalt-rich alliage blanc (an alloy of cobalt, copper, and iron) at plants within Congo (Kinshasa) prior to export, but most was not, and much of the unprocessed heterogenite was exported illegally. In 2005, high copper prices and the availability of localized high-grade copper ores resulted in a shift by some artisanal miners to gather copper-rich malachite ores and a shift by some smelters to produce copper products. Other factors that could affect future cobalt mining in Congo (Kinshasa) included decreasing heterogenite ore grades, higher freight rates

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and lower availability of trucks, political desire to reduce artisanal mining and the direct export of cobalt ores, and an increased interest by international mining companies to develop projects in Congo (Kinshasa) (Metal Bulletin, 2005b; Grant, 2006; Global Witness, 2006, p. 4-5, 13, 15, 17).

Kababankola Mining Co. S.P.R.L. (KMC) mined copper-cobalt ores from open pit operations in Gécamines' Central Group and processed the ores at the nearby Kakanda concentrator, which it operated under lease from Gécamines. Concentrates from KMC's mining operations were either exported or toll-treated at Gécamines' Shituru refinery in Likasi. KMC was a joint venture between Tremalt Ltd. (a private company based in the British Virgin Islands) (80%) and Gécamines (20%) (Kababankola Mining Co. S.P.R.L., undated a§, b§).

Gécamines and L'Enterprise Générale Malta Forrest S.P.R.L. produced copper-cobalt concentrates from the Luiswishi Mine, which were sold under a long-term supply contract to OMG.

The Big Hill smelter at Lubumbashi, which was operated by Société pour le Traitement du Terril de Lubumbashi (a joint venture between Gécamines, OMG, and S.A. Groupe George Forrest), processed stockpiled slag to produce a cobalt-copper alloy containing 17% to 19% cobalt, which was sold to OMG's Kokkola refinery. In 2005, the smelter was shut down for approximately 4 months for scheduled maintenance and production improvements. During the year, the smelter produced alloy containing 2,259 t of cobalt, down from the 2,894 t produced in 2004 (OM Group, Inc., 2006, p. 5; George Forrest International S.A., 2006§).

Feza Mining SPRL (a joint venture between Comide SPRL and Wanbao Resources Corp.) built a smelter in Likasi with the capacity to produce 1,000 t/yr of cobalt in copper-cobalt alloy. Other smelters producing cobalt-bearing alloys included Gécamines' Fonderie Electrique de Panda and M.A.D.S.A.'s Four Electrique Luilu Cobalt (FELCO) project (Metal Bulletin, 2006; Feza Mining SPRL, 2006a§, b§).

Chemaf S.P.R.L. produced cobalt carbonate at its plant in Lubumbashi from ores extracted from the nearby Etoile Mine. In 2005, the company increased the plant's capacity to 4,000 t/yr of contained cobalt. Central African Mining & Exploration Company plc (CAMEC) began commissioning its newly constructed cobalt carbonate plant at Kambove. The plant had an initial capacity of 1,400 t/yr of contained cobalt, which could be doubled at a later time. Numerous other cobalt carbonate plants reportedly were being built in Congo (Kinshasa) by various Chinese organizations (Central African Mining & Exploration Company plc, 2006; Cobalt Development Institute, 2006a; Chemaf S.P.R.L., undated§).

Metorex Ltd. began constructing phase I of its Ruashi project. For this phase, Metorex was moving the flotation plant from its South African O'Okiep copper operation to Ruashi, and reconfiguring it to treat copper and cobalt oxide minerals stockpiled by Gécamines from past mining operations at Ruashi and Etoile. The resulting concentrates were to be refined in Zambia at Metorex's Sable Zinc refinery (as discussed in the "Zambia" portion of the "World Review" section of this report). During the year, Metorex worked on a feasibility study for phase II of the project, which would entail mining the Ruashi ore body by open pit methods and processing the ores onsite at an expanded flotation plant and newly constructed acid leaching-SX-EW refinery. An estimated 40,000 t/yr of copper metal and 3,000 t/yr of cobalt metal would be produced from phase II. The Congo (Kinshasa) operating company for the project was Ruashi Mining SPRL, which was 80%-owned by Ruashi Holdings (Pty.) Ltd. (a subsidiary of Metorex Ltd.) and 20% by Gécamines (Metorex Ltd., 2004, 2005, p. 5, 18-19).

Adastra Minerals Inc. continued to study the feasibility of proceeding with the Kolwezi Tailings Project, which involved the recovery of copper and cobalt from oxide tailings produced from past operations at Gécamines Kolwezi concentrator. In August, Congo (Kinshasa)'s Ministry of Mines approved the project's environmental adjustment plan; this was the official endorsement that project development could proceed. The feasibility study was based on a processing plant with initial production levels of approximately 30,000 t/yr of copper and 5,500 t/yr of cobalt. Adastra expected to complete the feasibility study and make a go-ahead decision on the project in 2006. At yearend, ownership of Kingamyambo Musonoi Tailings s.a.r.l., the company that held the tailings exploration permit for the project, was 65% Congo Mineral Development Ltd. (a wholly owned subsidiary of Adastra), 12.5% Gécamines, 10% Industrial Development Corp. of South Africa Ltd., 7.5% International Finance Corp., and 5% Government of Congo (Kinshasa) (Adastra Minerals Inc., 2006, p. 17, 22-25).

Africo Resources Ltd. studied the feasibility of developing the Kalukundi copper-cobalt deposit, which is approximately 65 km northeast of Kolwezi. Africo held an option to acquire a 75% interest in the deposit, which contained a measured and indicated resource of 12.2 Mt, grading 2.45% copper and 0.61% cobalt and an additional inferred resource of 15.0 Mt grading 2.63% copper and 0.58% cobalt (Rubicon Minerals Corp., 2006, p. 36-37).

KGHM Polska Miedź S.A. evaluated a project to build a hydrometallurgical processing plant in Congo (Kinshasa) to treat copper-cobalt ores from the Kimpe deposit. The company expected to decide on whether to proceed with the project in 2006 (KGHM Polska Miedź S.A., 2006, p. 12, 17).

Tenke Mining Corp. received formal approval from Gécamines and the Government of Congo (Kinshasa) for the development of the Tenke Fungurume project. Following receipt of the approval, Phelps Dodge Corp. exercised its option to acquire a controlling interest in the project, and the force majeure, which had been in place since 1999, was lifted. Tenke Fungurume, which is approximately 175 km northwest of Lubumbashi, has been described as the largest undeveloped high-grade copper-cobalt project in the world. The companies hoped to update a previous feasibility study on the project by mid-2006, so that production could begin in late 2008 or early 2009. Initial production would be 110,000 t/yr of copper metal and 8,800 t/yr of cobalt in various forms, depending on market demand. At yearend, ownership of the project was 57.75% Phelps Dodge, 24.75% Tenke Mining Corp., and 17.5% Gécamines (Tenke Mining Corp., 2006, p. 3-9; Phelps Dodge Corp., 2006§).

Kamoto Copper Company SARL [a joint venture between Kinross Forrest Ltd. (75%) and Gécamines (25%)] studied the feasibility of rehabilitating Gécamines' Kamoto Mine and associated facilities west of Kolwezi. The assets included the mine, which is a large underground copper-cobalt mine that has had only limited production since it suffered a major collapse in 1990, various open pit oxide resources, the Kamoto concentrator, and the Luilu copper and cobalt refinery. The joint

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venture planned to restore the mines and facilities incrementally over a period of years, maintaining existing equipment and process flow sheets unless it was determined that the equipment was beyond repair or that new process technology would offer sufficient advantages (du Plessis and Heili, 2005, p. 1.7-1.8).

Privately owned Global Enterprises Corporate Ltd. (GEC) reportedly studied the feasibility of reopening the Kamoto Oliviera Virgule (KOV) open pit mine in a joint venture with Gécamines (75% GEC and 25% Gécamines). The KOV Mine, which flooded after Gécamines ceased production there, had been a significant past producer of copper and cobalt (Metal Bulletin, 2005c).

Industrial Copper Systems Ltd. (ICS) installed a pilot-scale copper-cobalt processing plant south of Gécamines' Shituru refinery. The plant, which was designed to produce metal and chemicals by using a process based on Electrometals Technologies Ltd.'s electrowinning cell technology, began production in June. ICS hoped to acquire the rights from Gécamines to process the nearby Panda tailings (Industrial Copper Systems Ltd., 2005§).

Cuba.—Moa Nickel S.A. [part of the joint venture between Sherritt (50%) and General Nickel (50%)] mined nickel-cobalt laterites at Moa Bay in Holguin Province and produced mixed sulfides containing 33,006 t of nickel and cobalt, a slight decrease from the 33,534 t produced in 2004. All of the mixed sulfides were sent to the joint venture's Fort Saskatchewan refinery in Canada. Sherritt and General Nickel agreed to expand production at Moa Bay to 49,000 t/yr of nickel-cobalt sulfides. Construction was to begin during the second quarter of 2006 so that commissioning could begin by the second quarter of 2008. General Nickel was to ensure the granting of concessions for ore reserves for 25 years of production at the new rate (Sherritt International Corp., 2006, p. 3, 23, 26).

Unión del Níquel S.A. also mined and refined nickel-cobalt laterites in Holguin Province. Nickel-cobalt mixed sulfides produced at the Ernesto Che Guevara Mining and Metallurgical Combine at Punta Gorda were exported to Jinchuan in China (McCutcheon, 2004, p. 38.45-38.46). Nickel and cobalt of Cuban origin cannot be imported into the United States because of a United States embargo on imports from Cuba.

Finland.—OMG's Kokkola Chemicals Oy refinery recovered cobalt from cobalt-copper alloy from the Big Hill smelter in Congo (Kinshasa), cobalt solution from the company's Harjavalta nickel refinery, and other materials, including low-grade ores and concentrates, sulfides, metallic feeds, and secondary (scrap) materials. The company's production of cobalt metal powders, briquettes, oxides, and compounds was 8,171 t, 4% higher than the 7,893 t produced in 2004 (Geological Survey of Finland, 2006§; OM Group, Inc., undated§).

Vulcan Resources Ltd. began to study the feasibility of developing its Kylylahti copper-cobalt-nickel-gold deposit, which is 24 km from Outokumpu in eastern Finland. Kylylahti had a resource of 7.4 Mt grading 1.0% copper, 0.2% cobalt, 0.2% nickel, and 0.6 g/t gold (Vulcan Resources Ltd., 2006).

France.—The Eramet Group produced cobalt chloride at its refinery at Sandouville near Le Havre. Feed for the refinery was nickel matte imported from Eramet subsidiary Le Nickel SLN's Doniambo smelter in New Caledonia.

India.—According to the Cobalt Development Institute (2006c), India's cobalt production more than doubled as compared with that of 2004. Nicomet Industries Ltd. and Rubamin Ltd. were the leading producers. During the year, Nicomet increased the capacity of its plant in Cuncolim, Goa State, to 90 metric tons per month of cobalt (1,080 t/yr of cobalt), and Rubamin expanded the capacity of its Halol plant near Vadodara, Gujarat State, to 500 t/yr cobalt. India relies on imports of heterogenite from Congo (Kinshasa) as its cobalt feed material (Metal Bulletin, 2005d; Agrawal, Porwal, and Koppiker, 2006; Rubamin Ltd., 2005§).

Indonesia.—State-owned PT Antam Tbk exported lateritic nickel-cobalt ore to QNI's Yabulu refinery in Australia. Antam and other companies worked on projects to explore and develop Indonesia's nickel-cobalt laterite resources.

Japan.—Sumitomo Metal Mining Co., Ltd. produced electrolytic cobalt as a byproduct of nickel production at its Niihama nickel refinery in Ehime Prefecture. The Niihama refinery processed nickel matte from P.T. Inco in Indonesia and nickel-cobalt mixed sulfide from the Coral Bay Nickel Corp. plant in the Philippines; Sumitomo's long-term contract with WMC for nickel matte expired in March. Sumitomo planned to increase the capacity of Niihama to approximately 45,000 t/yr of nickel and 1,100 t/yr of cobalt to accommodate the output from Coral Bay (Metal Bulletin, 2002; WMC Resources Ltd., 2005, p. 29; Cobalt Development Institute, 2006c).

Madagascar.—Dynatec Corp. completed a feasibility study on developing the Ambatovy nickel laterite deposit, which is 130 km east of Antananarivo. The study confirmed the potential for an open pit mining operation, including an ore preparation plant; a 195-km pipeline to transport slurried ore to a pressure acid leaching plant, which would be built near the Port of Toamasina and produce an intermediate nickel-cobalt sulfide product; and a metals refinery for the production of cobalt and nickel metal powders. The project would have the capacity to produce 60,000 t/yr of nickel and 5,600 t/yr of cobalt during a 27-year life. At yearend, project partners Dynatec (75%) and Sumitomo (25%) were in discussion with other parties interested in joining the project (Dynatec Corp., 2006, p. 7-9, 12).

Mexico.—Baja Mining Corp. studied the feasibility of developing the Boleo copper-cobalt-zinc deposit near Santa Rosalia on the east coast of the Baja California Peninsula. Baja was considering underground mining using continuous mining machines, supplemented by production from open pits during some years. The operation would include a hydrometallurgical processing plant that would produce up to 50,000 t/yr of copper cathode, 10,000 t/yr of zinc as sulfate, 2,000 t/yr of cobalt as carbonate or cathode, and possibly 35,000 to 65,000 t/yr of manganese as carbonate. During the year, Baja began trial underground mining to test the mechanized mining method at Boleo and collect geotechnical and operational information for mine design (Baja Mining Corp., 2006).

Morocco.—Cie. de Tifnout Tiranimine (CTT) mined cobalt-arsenic deposits at Bou Azzer and produced concentrates. At its Guemassa hydrometallurgical complex north of Marrakech, CTT refined the concentrates and cobalt hydroxides produced from tailings generated by past mining at Bou Azzer and produced cobalt cathode. The company planned to increase its production capacity by 10% to 20% in 2007 (Akalay, 2006).

New Caledonia.—Lateritic nickel-cobalt ore was exported to QNI's Yabulu refinery for processing. Nickel matte from Le

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Nickel SLN's Doniambo smelter was sent to Eramet's refinery in Sandouville, France, where it was refined into nickel cathode, nickel chloride, and cobalt chloride, listed in decreasing order of magnitude.

Inco began construction of its Goro nickel-cobalt laterite project in southern New Caledonia. The project comprised an integrated mining and pressure acid leaching-solvent extraction processing facility with a planned capacity of approximately 60,000 t/yr of nickel as oxide and 4,300 to 5,000 t/yr of cobalt as carbonate. At yearend, ownership of Goro was as follows: Inco (71%), Sumic Nickel Netherlands b.v. (a joint venture between Sumitomo and Mitsui & Co., Ltd.) (21%), and Société de Participation Minière du Sud Calédonien SAS (8%). Inco expected to begin production at Goro in late 2007 (Inco Ltd., 2006b, p. 50-52).

Norway.—Falconbridge's production of cobalt at its Nikkelverk refinery increased by 7% compared with production in 2004. During 2005, 20% of the cobalt produced at Nikkelverk originated from Falconbridge mines in Canada, and 80% originated from custom feeds. The custom feed included matte from Botswana, which Falconbridge processed under a long-term agreement with BCL Ltd. (Falconbridge Ltd., 2006, p. 21-23).

Papua New Guinea.—China Metallurgical Construction Group Corp. (MCC) exercised its option to take an 85% interest in the Ramu nickel-cobalt laterite project in Madang Province. Under the joint-venture agreement with Highlands Pacific Ltd., MCC would be responsible for project financing, would manage and operate the project, and would have the right to purchase all of the project's future production. The feasibility study and subsequent updates were based on pressure acid leaching technology to produce 32,800 t/yr of nickel cathode and 3,200 t/yr of cobalt as cathode or an intermediate product during a 20-year life, with the potential to increase mine life by an additional 15 to 20 years. Permitting and development approvals were in place for the project. MCC planned to begin construction in 2006 (Highlands Pacific Ltd., 2006, p. 2, 15-16).

Philippines.—Lateritic nickel-cobalt ore from the Philippines was exported to QNI's Yabulu refinery for processing.

Coral Bay Nickel Corp. [a joint venture between Sumitomo (54%), Mitsui & Co., Ltd. and Sojitz Corp. (18% each), and Rio Tuba Nickel Mining Corp. (10%)] began commercial production from its high-pressure acid-leaching plant at the Rio Tuba nickel mine on Palawan Island and was producing at capacity by yearend. The plant used stockpiled low-grade laterite ores as feed material. All of the plant's nickel-cobalt mixed sulfide intermediate product, containing approximately 10,000 t/yr of nickel and 700 t/yr of cobalt, was to be refined at Sumitomo's Niihama nickel refinery in Japan. During the year, Coral Bay Nickel studied the feasibility of doubling the plant's capacity (Sumitomo Metal Mining Co., Ltd. 2005; Manila Bulletin Online, 2005§).

Russia.—According to the Cobalt Development Institute (2006c), OJSC MMC Norilsk Nickel, which was Russia's leading cobalt producer, produced 4,748 t of cobalt, 5% more than the 4,524 t produced in 2004. Norilsk Nickel conducted nickel-copper sulfide mining and refining at Norilsk on the Taimyr Peninsula and at Monchegorsk on the Kola Peninsula. Cobalt from ores mined at Norilsk was refined at Norilsk operations; cobalt from ores mined on the Kola Peninsula was toll refined by OJSC Ufaleynickel at its refinery at Verkhniy Ufaley in the Ural Mountains. Norilsk was considering a change from this tolling arrangement to producing high-grade cobalt at its Kola operation (Metal Bulletin, 2004; Astafiev, 2005, p. 6).

Ufaleynickel planned to increase its nickel and cobalt production levels in 2006 by processing oxide nickel ore mined from its Serov field and by modernizing its hydrometallurgical plant (Interfax International Ltd., 2006).

South Africa.—Cobalt was mined as a byproduct from six PGM mines and one nickel mine (Harding, 2005). Two companies produced refined cobalt as a byproduct of platinum refining. Rustenburg Base Metal Refiners Pty. Ltd. (a subsidiary of Anglo American plc) produced cobalt sulfate at its refinery near Rustenburg, Northwest Province, and Impala Platinum Ltd. produced cobalt metal powder at its base-metals refinery near Springs, Gauteng Province. Some of the cobalt produced by Impala was recovered from concentrates produced at the Mimosa platinum mine in Zimbabwe.

African Rainbow Minerals Ltd. and LionOre formed a joint venture to study the feasibility of using the Activox process in the expansion of the Nkomati nickel sulfide mine in Mpumalanga Province. The expanded operation would produce an estimated 16,500 t/yr of nickel cathode, 7,900 t/yr of copper cathode, 950 t/yr of cobalt carbonate, plus palladium and platinum during a 16-year mine life. In recent years, sales of cobalt in nickel concentrates have been 80 to 100 t/yr (Anglovaal Mining Ltd., 2004, p. 281-289; LionOre Mining International Ltd., 2005; African Rainbow Minerals Ltd., 2006, p. 39).

Umicore discontinued operations at its cobalt plant in Roodepoort during the June quarter. The plant had treated low-grade cobalt-containing residues to produce cobalt compounds (n.v. Umicore s.a., 2006, p. 5).

Spain.—Rio Narcea Gold Mines, Ltd. began commercial production of copper-nickel-PGM concentrate from its Aguablanca open pit nickel sulfide mine and processing plant in Badajoz Province near the boundaries of Huelva and Sevilla Provinces in southwestern Spain. At planned production rates, the concentrates were expected to contain approximately 200 t/yr of cobalt (Rio Narcea Gold Mines, Ltd., 2005, p. 6; 2006).

Turkey.—European Nickel PLC demonstrated the viability of processing nickel laterite ores by acid heap leaching and completed a feasibility study on its Çaldağ deposit in western Turkey. Depending on the availability of financing, European Nickel planned to start building a full-scale leaching plant during the first half of 2006, begin mining and building the first ore heap by late 2006, and begin producing nickel-cobalt mixed hydroxide in 2007. At full operation, production was expected to be 21,400 t/yr of nickel and 1,000 t/yr of cobalt in mixed hydroxide. BHP Billiton has worked with European Nickel on the project and has an offtake agreement with the company for some of the mixed hydroxide (European Nickel PLC, 2005).

Uganda.—Kasese Cobalt Co. Ltd. (75% Blue Earth Refineries Inc. and 25% Kilembe Mines Ltd.) produced cobalt cathode from stockpiled pyrite concentrates by using a bacterial leaching-SX-EW process at its cobalt refinery in southwestern Uganda. Uganda Gold Mining Ltd. began an exploration program and feasibility study on reopening the Kilembe copper-cobalt mine in western Uganda. The study was considering various alternatives for treating concentrates produced from

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Kilembe, including the use of the Kasese refinery (Blue Earth Refineries Inc., 2005, p. 13; Uganda Gold Mining Ltd., 2005).

Vietnam.—Asian Mineral Resources Ltd. completed a feasibility study on developing the Ban Phuc nickel sulfide deposit, which is approximately 160 km west of Hanoi in Son La Province. Asian Mineral Resources planned to mine the deposit by underground methods and produce a nickel-copper flotation concentrate, containing an average of approximately 110 t/yr of cobalt during the mine's 6-year life (Ausenco International Pty. Ltd., 2005, p. 1, 58).

Zambia.—Mopani Copper Mines Plc [owned by Glencore International AG (73.1%), First Quantum Minerals Ltd. (16.9%), and ZCCM Investments Holdings plc (10%)] produced 1,744 t of cobalt metal at its Nkana cobalt refinery, 12% less than the 2,022 t produced in 2004. The decrease in production was attributed to a decrease in the availability of cobalt concentrates in Zambia. Most of the cobalt originated from the company's Nkana underground copper-cobalt mine. Mopani anticipated that, as a result of increasing its copper production, the company's cobalt production would be 2,000 to 2,500 t/yr by 2007 (Cobalt Development Institute, 2006a, c).

Chambishi Metals plc [owned by J&W Holding AG (90%) and ZCCM Investments Holdings (10%)] produced 3,648 t of cobalt metal at its Chambishi cobalt refinery, a 3% decrease from the 3,769 t produced in 2004. The refinery's main feed materials were slag from a stockpile at Nkana and concentrates from J&W subsidiary Luanshya Copper Mines Plc's Baluba copper-cobalt mine. Chambishi also processed purchased raw materials, such as alliage blanc, concentrates, and heterogenite. During the year, Chambishi's cobalt production was limited by delays in refurbishing the Baluba Mine, which resulted in a decrease in the availability of concentrates (Metal Bulletin, 2005a; Brown, 2006; Cobalt Development Institute, 2006c).

Konkola Copper Mines plc (KCM) [owned by Vedanta Resources plc (51%), Zambia Copper Investments Ltd. (28.4%), and ZCCM Investments Holdings (20.6%)] mined copper ores from its Nchanga and Konkola operations. KCM ceased cobalt production in 2004 owing to a depletion of cobalt resources at the Nchanga open pit. Cobalt-bearing slag from the company's Nkana Smelter was stockpiled for future reclamation (Konkola Copper Mines plc, undated§).

Metorex's Chibuluma West Mine ceased operations in March. Copper-cobalt ore from the mine had been processed at the company's Chibuluma South concentrator, and the concentrates had been sold to Mopani. During the year, Metorex worked on refurbishing its Sable Zinc leaching and electrowinning plant near Kabwe. The company was adding a solvent extraction unit and expanding the plant so that it could produce approximately 10,000 t/yr of copper metal and 1,000 t/yr of cobalt as carbonate. Metorex planned to begin processing copper-cobalt concentrates produced at its Ruashi operations in Congo (Kinshasa) in 2006 (Metorex Ltd., 2005, p. 5, 17-19; 2006).

TEAL Exploration & Mining Inc. studied the feasibility of developing the Mwambashi copper project in a joint venture with Korea Zinc Corp. The Mwambashi project is about 35 km from Kitwe and had an estimated indicated mineral resource of 8.6 Mt containing 2.43% copper and 0.066% cobalt. TEAL was considering open pit mining the oxidized minerals in the upper portion of the deposit, possibly followed by underground mining (Verbeek and others, 2005, p. 9, 14).

Albidon Ltd. studied the feasibility of developing the Enterprise nickel sulfide deposit at its Munali nickel project in southern Zambia. The deposit's indicated and inferred resource estimate was 6.93 Mt grading 1.4% nickel, 0.2% copper, 0.08% cobalt, and 1.0 g/t PGMs. Albidon hoped to begin producing nickel concentrates from Munali in 2007 (Albidon Ltd., 2005).

Outlook

World demand for cobalt is expected to continue to increase in coming years. Industries that could show significant increases in cobalt demand include superalloys for civil aviation, power generation, and flue gas desulfurization equipment; catalysts for the production of chemicals used to make polyethylene terephthalate and for gas-to-liquid production of synthetic liquid fuels; and rechargeable batteries for portable electronic devices and hybrid electric vehicles. Some of the increase in demand from the battery sector is being dampened, however, by substitution of cobalt with other, less expensive metals (Cobalt Development Institute, 2006b).

World production of refined cobalt is also expected to continue to increase. Many producers plan to increase their production and/or capacity levels at existing operations, and various new nickel and copper-cobalt projects and a primary cobalt project are in progress. Production in 2006 will include cobalt refined from Voisey's Bay concentrates, although some of that production may replace declining production from Inco's other operations in Canada. The next production from the larger of the new projects, in terms of refined cobalt output, is not expected before late 2007 (Cobalt Development Institute, 2006a, b; Searle, 2006). In addition to production, recycled cobalt and NDS inventory releases will continue to contribute to supply. Much of the cobalt from the NDS, which has been a significant source of supply for more than a decade, however, has been sold. As of July 31, 2006, only 1,470 t of uncommitted cobalt remained in the NDS, which represented about 1 year's supply at the current rate of disposal.

Some analysts predict that the balance between cobalt supply and demand could be tight in the next few years. The near-term increase in demand will be met primarily from existing producers, including materials exported from Congo (Kinshasa) to China (Cobalt Development Institute, 2006b). Searle (2006) stated that there continues to be a risk for cobalt demand to be constrained by supply. He predicted that future cobalt prices would have to remain above $12 per pound through 2010 in order for exports of cobalt materials from Congo (Kinshasa) to continue. From January through July 2006, the price of cobalt cathode reported by Platts Metals Week remained in the $12.75 to $16.15 per pound range.

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TABLE 1
SALIENT COBALT STATISTICS[1]

(Metric tons, cobalt content, unless otherwise specified)

	2001	2002	2003	2004	2005
United States:					
Consumption:					
Reported	9,540	7,880	7,590	8,450	8,430
Apparent	11,800	9,830	10,000	9,920	11,900
Imports for consumption	9,410	8,450	8,080	8,720	11,100
Exports	3,210	2,080	2,710	2,500	2,440
Stocks, December 31:					
Industry[2]	809	858	649	719	664
U.S. Government[3]	7,200 e	6,680	4,290	2,660	1,550
Price, metal[4] dollars per pound	10.55	6.91	10.60	23.93	15.96
World, production:[e]					
Mine	44,800 r	50,600 r	50,800 r	57,100 r	57,900
Refinery	38,700 r	40,800 r	43,800	49,100	54,900

[e]Estimated. [r]Revised.

[1]Data are rounded to no more than three significant digits, except prices.

[2]Stocks held by cobalt processors and consumers.

[3]Defense National Stockpile Center. Includes material committed for sale pending shipment.

[4]Annual average U.S. spot price for minimum 99.8% cobalt cathode reported by Platts Metals Week.

TABLE 2
U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE
SALES AND SHIPMENTS[1]

(Metric tons, cobalt content)

	2004	2005
Sales:		
Fiscal year[2]	1,920	1,120
Calendar year	987	880
Shipments:[3]		
Fiscal year[2]	2,220	893
Calendar year	1,630	1,110

[1]Data are rounded to no more than three significant digits.

[2]Twelve-month period ending September 30 of year stated.

[3]Calculated from yearend inventory levels.

Source: Defense National Stockpile Center.

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TABLE 3

U.S. REPORTED CONSUMPTION AND STOCKS OF COBALT[1, 2]

(Metric tons, cobalt content)

	2004	2005
Consumption by end use:		
Steels	722	857
Superalloys	3,650	4,140
Alloys, excludes steels and superalloys:		
Magnetic alloys	396	337
Other alloys[3]	627	227
Cemented carbides[4]	765	763
Chemical and ceramic uses	2,230	2,040
Miscellaneous and unspecified	63	63
Total	8,450	8,430
Consumption by form:		
Chemical compounds, organic and inorganic[5]	2,040	1,860
Metal	4,110	4,550
Purchased scrap	2,300	2,030
Total	8,450	8,430
Stocks, December 31:[6]		
Chemical compounds, organic and inorganic[5]	223	209
Metal	379	383
Purchased scrap	117	72
Total	719	664

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes estimates.

[3]Includes nonferrous alloys, welding materials, and wear-resistant alloys.

[4]Includes diamond tool matrices, cemented and sintered carbides, and cast carbide dies or parts.

[5]Includes oxides.

[6]Stocks held by cobalt processors and consumers.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY FORM[1]

	2004			2005		
	Gross weight (metric tons)	Cobalt content[2] (metric tons)	Value (thousands)	Gross weight (metric tons)	Cobalt content[2] (metric tons)	Value (thousands)
Metal[3]	7,250	7,250	$311,000	9,350	9,350	$312,000
Oxides and hydroxides	1,300	934	45,100	1,310	943	35,100
Other forms:						
Acetates	230	55	2,550	260	62	2,250
Carbonates	453	208	10,300	985	453	15,300
Chlorides	327	82	3,220	189	47	1,480
Sulfates	705	190	6,030	762	206	5,750
Grand total	10,300	8,720	378,000	12,900	11,100	372,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Estimated from gross weights.

[3]Unwrought cobalt, excluding alloys and waste and scrap.

Source: U.S. Census Bureau.

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TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY[1]

Country of origin	Metal[2]			Oxides and hydroxides			Other forms[3]			Total		
	Gross weight (metric tons)	Cobalt content[4] (metric tons)	Value[5] (thousands)	Gross weight (metric tons)	Cobalt content[4] (metric tons)	Value[5] (thousands)	Gross weight (metric tons)	Cobalt content[4] (metric tons)	Value[5] (thousands)	Gross weight (metric tons)	Cobalt content[4] (metric tons)	Value[5] (thousands)
2004:												
Australia	448	448	$18,600	--	--	--	--	--	--	448	448	$18,600
Belgium	668	668	20,200	451	325	$17,700	--	--	--	1,120	992	37,900
Brazil	16	16	585	--	--	--	(6)	(6)	$5	17	16	589
Canada	1,120	1,120	36,900	1	1	45	--	--	--	1,130	1,130	37,000
China	429	429	18,400	188	135	4,660	462	136	5,250	1,080	701	28,300
Congo (Kinshasa)	16	16	712	--	--	--	--	--	--	16	16	712
Finland	357	357	19,600	361	260	12,300	733	257	11,800	1,450	874	43,800
France	56	56	3,570	24	18	1,280	--	--	--	81	74	4,850
Germany	33	33	1,550	5	4	202	--	--	--	38	37	1,760
India	--	--	--	--	--	--	171	46	1,370	171	46	1,370
Japan	164	164	9,460	(6)	(6)	13	57	14	772	221	178	10,200
Korea, Republic of	71	71	1,620	--	--	--	--	--	--	71	71	1,620
Norway	1,420	1,420	65,200	--	--	--	--	--	--	1,420	1,420	65,200
Philippines	--	--	--	--	--	--	83	27	758	83	27	758
Russia	1,630	1,630	79,800	--	--	--	--	--	--	1,630	1,630	79,800
South Africa	110	110	3,270	--	--	--	--	--	--	110	110	3,270
Sweden	8	8	315	--	--	--	--	--	--	8	8	315
Uganda	50	50	2,110	--	--	--	--	--	--	50	50	2,110
United Kingdom	12	12	579	240	173	7,940	155	41	1,930	407	226	10,400
Zambia	618	618	27,700	--	--	--	--	--	--	618	618	27,700
Other	11	11	347	27	19	1,020	53	14	153	92	45	1,520
Total	7,250	7,250	311,000	1,300	934	45,100	1,720	536	22,100	10,300	8,720	378,000
2005:												
Australia	313	313	10,300	--	--	--	--	--	--	313	313	10,300
Belgium	393	393	12,700	495	357	14,200	42	19	714	930	768	27,600
Brazil	305	305	9,770	--	--	--	--	--	--	305	305	9,770
Canada	818	818	30,200	(6)	(6)	4	--	--	--	818	818	30,200
China	576	576	20,500	155	111	3,440	767	282	8,460	1,500	970	32,400
Congo (Kinshasa)	25	25	780	--	--	--	--	--	--	25	25	780
Finland	687	687	25,200	296	213	7,350	743	289	9,780	1,730	1,190	42,400
France	24	24	1,550	34	24	1,620	1	(6)	23	59	49	3,190
Germany	8	8	411	1	1	151	--	--	--	9	9	561
India	23	23	695	--	--	--	370	100	2,720	393	123	3,410
Japan	218	218	9,650	10	7	502	--	--	--	228	225	10,200
Korea, Republic of	24	24	413	--	--	--	--	--	--	24	24	413
Morocco	342	342	10,300	--	--	--	--	--	--	342	342	10,300

See footnotes at end of table.

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TABLE 5—Continued

U.S. IMPORTS FOR CONSUMPTION OF COBALT, BY COUNTRY[1]

	Metal[2]			Oxides and hydroxides			Other forms[3]			Total		
Country of origin	Gross weight (metric tons)	Cobalt content[4] (metric tons)	Value[5] (thousands)	Gross weight (metric tons)	Cobalt content[4] (metric tons)	Value[5] (thousands)	Gross weight (metric tons)	Cobalt content[4] (metric tons)	Value[5] (thousands)	Gross weight (metric tons)	Cobalt content[4] (metric tons)	Value[5] (thousands)
2005—Continued:												
Norway	2,670	2,670	$89,200	--	--	--	--	--	--	2,670	2,670	$89,200
Philippines	--	--	--	--	--	--	94	34	$1,310	94	34	1,310
Russia	1,700	1,700	50,700	--	--	--	--	--	--	1,700	1,700	50,700
South Africa	204	204	7,280	20	14	$705	39	9	200	263	228	8,190
Sweden	7	7	142	--	--	--	--	--	--	7	7	142
Uganda	60	60	2,140	--	--	--	--	--	--	60	60	2,140
United Kingdom	14	14	496	290	209	6,910	138	35	1,550	442	258	8,950
Zambia	936	936	29,900	--	--	--	--	--	--	936	936	29,900
Other	(6)	(6)	15	9	7	240	3	1	18	13	8	273
Total	9,350	9,350	312,000	1,310	943	35,100	2,200	769	24,800	12,900	11,100	372,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Unwrought cobalt, excluding alloys and waste and scrap; includes cobalt cathode and cobalt metal powder; may include intermediate products of cobalt metallurgy.

[3]Includes cobalt acetates, cobalt carbonates, cobalt chlorides, and cobalt sulfates.

[4]Estimated from gross weights.

[5]Customs value.

[6]Less than ½ unit.

Source: U.S. Census Bureau, minor adjustments by the U.S. Geological Survey.

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TABLE 6

U.S. EXPORTS OF COBALT IN 2005, BY COUNTRY[1, 2]

Country of destination	Metal[3] Gross weight (metric tons)	Metal[3] Value[4] (thousands)	Oxides and hydroxides Gross weight (metric tons)	Oxides and hydroxides Value[4] (thousands)	Acetates Gross weight (metric tons)	Acetates Value[4] (thousands)	Chlorides Gross weight (metric tons)	Chlorides Value[4] (thousands)	Total Cobalt content[5] (metric tons)	Total Value[4] (thousands)
Belgium	732	$30,300	(6)	$3	141	$609	--	--	766	$31,000
Brazil	4	195	2	47	77	597	--	--	24	839
Canada	121	3,550	103	1,990	77	708	2	$22	214	6,270
China	13	414	--	--	15	162	--	--	16	576
France	103	3,670	7	34	--	--	--	--	108	3,700
Germany	86	3,350	--	--	--	--	--	--	86	3,350
India	15	582	--	--	19	143	--	--	20	724
Ireland	232	6,370	--	--	--	--	(6)	7	232	6,380
Japan	116	4,670	516	11,300	7	46	--	--	489	16,000
Korea, Republic of	17	619	--	--	25	239	--	--	23	858
Mexico	13	488	52	844	305	972	2	28	124	2,330
Portugal	--	--	40	65	--	--	--	--	29	65
Singapore	5	222	64	1,540	--	--	--	--	50	1,760
Spain	12	89	2	68	20	166	--	--	18	323
Taiwan	11	315	9	408	6	54	--	--	19	777
United Kingdom	126	2,340	17	611	(6)	6	(6)	4	138	2,960
Other	67	3,370	17	221	7	59	--	--	81	3,650
Total	1,670	60,600	829	17,100	699	3,760	4	60	2,440	81,500

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]In addition to the materials listed, the United States exports cobalt ores and concentrates and wrought cobalt and cobalt articles.

[3]Includes unwrought cobalt, powders, waste and scrap, and mattes and other intermediate products of cobalt metallurgy.

[4]Free alongside ship value.

[5]Estimated from gross weights.

[6]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 7
WORLD ANNUAL COBALT REFINERY CAPACITY, DECEMBER 31, 2005[1, 2]

(Metric tons, cobalt content)

Country	Capacity
Australia[e]	4,500
Belgium[e]	1,800
Brazil[e]	1,200
Canada[e]	5,300
China[e]	25,000
Congo (Kinshasa)[e, 3]	15,000
Finland	10,000
France	600
India	1,560
Japan	600
Morocco[e]	1,650
Norway	5,200
Russia[e]	6,000
South Africa[e]	750
Uganda	720
Zambia	8,200
Total	88,100

[e]Estimated.
[1]Data are rounded to no more than three significant digits; may not add to total shown.
[2]Refinery products include cobalt metal, metal powders, oxides, and/or salts.
[3]Refurbishment necessary to achieve stated capacity.

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TABLE 8

COBALT: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, cobalt content)

Country[3]	2001	2002	2003	2004	2005[e]
Australia[e, 4]	6,300	6,700	6,900	6,700	6,000
Botswana[5]	325	269	294	223	200
Brazil	1,003 [r]	1,099 [r]	1,097 [r]	1,236 [r]	1,200
Canada[6]	5,326	5,148	4,327	5,060 [r]	5,533 [7]
China[e]	150	1,000	700	1,260 [r]	1,300
Congo (Kinshasa)[e, 8]	12,000 [r]	14,500	14,500 [r]	20,500 [r]	22,000
Cuba[9]	3,425 [r]	3,442 [r]	3,274 [r]	3,554 [r]	3,600
Kazakhstan[e, 10]	300	300	300	300	300
Morocco[11]	1,242	1,453	1,391	1,600 [e]	1,600
New Caledonia[e, 12]	1,400	1,400	1,400	1,400	1,200
Norway[e, 11]	100	100	--	--	--
Russia[e]	4,600	4,600	4,800	4,700	5,000
South Africa[e]	560	520	400	460	400
Zambia[e, 13]	8,000	10,000	11,300	10,000	9,300
Zimbabwe[14]	95	99 [r]	79	59	250
Total[e]	44,800 [r]	50,600 [r]	50,800 [r]	57,100 [r]	57,900

[e]Estimated. [r]Revised. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 18, 2006. Figures represent recoverable cobalt content of ores, concentrates, or intermediate products from cobalt, copper, nickel, platinum, or zinc operations.

[3]In addition to the countries listed, Indonesia, the Philippines, Poland, Spain, and Turkey are known to produce ores that contain cobalt, but information is inadequate to make reliable estimates of production. Other copper-, nickel-, platinum-, or zinc-producing nations may also produce ores containing cobalt as a byproduct component, but recovery is small or nil.

[4]Quantities of cobalt contained in intermediate or refined metallurgical products produced from Australian and imported ores. Cobalt content of lateritic nickel ore, nickel concentrate, and zinc concentrate originating in Australia, in metric tons, was estimated to be as follows: 2001—6,200; 2002—6,800; 2003—7,300; 2004—7,000; and 2005—7,100.

[5]Reported cobalt content of pelletized nickel-copper matte.

[6]Assay content of cobalt in concentrates produced. The cobalt content, in metric tons, of all products derived from ores of Canadian origins, including cobalt oxide shipped to the United Kingdom for further processing and nickel-copper matte shipped to Norway for refining, was reported to be as follows: 2001—2,112; 2002—2,065; 2003—1,842; 2004—2,085 (revised); and 2005—2,105.

[7]Reported figure.

[8]Cobalt content of concentrates, tailings, and slags. Includes the following estimates, in metric tons, of illegal production by artisanal miners: 2001-02—2,000; 2003—4,000; 2004—7,000; and 2005—7,000.

[9]Determined from reported nickel-cobalt content of sulfide production.

[10]Estimated cobalt content of only those ores from which it is assumed cobalt is recovered. Cobalt content of total ores mined is assumed to be 1,400 metric tons (2001-05).

[11]Cobalt content of concentrates.

[12]Quantities of cobalt contained in intermediate or refined metallurgical products (cobalt chloride and cobalt oxide hydroxide) produced from New Caledonian ores exported to Australia and France.

[13]Cobalt content of concentrates and slags.

[14]Cobalt content of intermediate products produced in Zimbabwe from ores originating in Botswana and Zimbabwe.

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TABLE 9

COBALT: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, cobalt content)

Country[3]	2001	2002	2003	2004	2005
Australia, metal, metal powder, oxide hydroxide[e]	3,470	3,700	3,840	3,880	3,150
Belgium, metal powder, oxide, hydroxide[4]	1,090	1,135	1,704	2,947	3,298
Brazil, metal	889	960	1,097	1,155	1,136
Canada, metal, metal powder, oxide	4,378	4,625	4,233	5,144	5,079
China, metal, metal powder, oxide, salts[e, 5]	1,470	1,840	4,580	8,000	12,700
Congo (Kinshasa), metal[6]	3,199 [r]	2,149 [r]	1,200 [e]	735	600
Finland, metal powder and salts[7]	8,100	8,240 [r]	7,989 [r]	7,893	8,171
France, chloride	199	176	181	199	280
India, metal and salts	250	270	255	545	1,220
Japan, metal	350	354	379	429	471
Morocco, metal	1,341	1,354	1,431	1,594 [r]	1,613
Norway, metal	3,314	3,994	4,556	4,670	5,021
Russia, unspecified[e, 8]	5,000	5,100	5,500	5,400	5,800
South Africa, metal powder and sulfate	373	352	271	309	268
Uganda, metal	634	450 [e]	--	436	638
Zambia, metal	4,657	6,144	6,620	5,791	5,422
Total[e]	38,700 [r]	40,800 [r]	43,800	49,100	54,900

[e]Estimated. [r]Revised. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 18, 2006. Figures represent cobalt refined from ores, concentrates, or intermediate products and do not include production of downstream products from refined cobalt.

[3]In addition to the countries listed, Germany and Poland may produce some cobalt, but information is inadequate to make reliable estimates of production.

[4]Production reported by n.v. Umicore s.a.; includes production from China and South Africa that is not otherwise included in this table.

[5]Production from domestic and imported ores and concentrates; excludes production by n.v. Umicore s.a. that is included under Belgium.

[6]Excludes production of cobalt in white alloy, matte, and slag that would require further refining.

[7]Production for 2001 reported by OM Group, Inc.; production for 2002-05 reported by the Geological Survey of Finland.

[8]Production reportedly includes metal, oxide, and salts; other forms may also have been produced.

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COLUMBIUM (NIOBIUM) AND TANTALUM

By Michael J. Magyar

Domestic survey data and tables were prepared by Robin C. Kaiser, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Neither columbium (niobium) nor tantalum was mined domestically because U.S. resources are of low grade. Some resources are mineralogically complex, and most are not currently recoverable. The last significant mining of columbium and tantalum in the United States was during the Korean conflict, when increased military demand resulted in columbium and tantalum ore shortages.

Columbium is vital as an alloying element in steels and in superalloys for aircraft turbine engines and is in greatest demand in industrialized countries. It is critical to the United States because of its defense-related uses in the aerospace, energy, and transportation industries. Substitutes are available for some columbium applications, but in most cases, they are less desirable.

Tantalum is a refractory metal that is ductile, easily fabricated, highly resistant to corrosion by acids, a good conductor of heat and electricity, and has a high-melting point. It is critical to the United States because of its defense-related applications in aircraft, missiles, and radio communications. Substitution for tantalum is made at either a performance or economic penalty in most applications.

Pyrochlore was the principal columbium mineral mined worldwide. Brazil and Canada, which were the dominant pyrochlore producers, accounted for most of the total estimated columbium mine production in 2005, with Brazil alone accounting for about 90%. The two countries, however, no longer export pyrochlore, only columbium in upgraded, valued-added forms produced from pyrochlore. Brazil exported mostly regular-grade ferrocolumbium and columbium oxide, and Canada exported regular-grade ferrocolumbium. The remaining columbium mineral supply came mostly from mining columbite and tantalite in Australia, Nigeria, and certain other African countries. Tantalum mineral was produced mostly from tantalite mining operations in Australia, which accounted for about 58% of total estimated tantalum mine production in 2005, and from other tantalum mine operations in Brazil, Canada, Mozambique, and certain African countries. The United States remained dependent on imports of columbium and tantalum materials; Brazil was the major source for columbium, and Australia was the major source for tantalum. Columbium price quotations reportedly remained stable, and overall price quotations for tantalite ore increased slightly. Overall reported consumption of columbium in the form of ferrocolumbium and nickel columbium increased. Tantalum consumption was unchanged. Summaries of important columbium and tantalum statistics are listed in tables 1 and 2, respectively.

Legislation and Government Programs

To ensure supplies of columbium and tantalum during an emergency, various materials have been purchased for the National Defense Stockpile (NDS) (table 3). For fiscal year 2005 (October 1, 2004, through September 30, 2005), the Defense National Stockpile Center (DNSC) disposed of columbium metal ingots totaling 9 metric tons (t) valued at $245,000. No columbium value was obtained for the 81 t of columbium contained in tantalum concentrates sold by the DNSC in fiscal year 2005. The DNSC's columbium carbide inventory was exhausted in fiscal year 2002, and the ferrocolumbium inventory was exhausted in fiscal year 2001. The DNSC also sold 7 t of tantalum contained in tantalum capacitor-grade metal valued at $829,000, 9 t of tantalum contained in tantalum metal ingots valued at $1.31 million, 9 t of tantalum contained in tantalum oxide valued at $910,000, and 220 t of tantalum contained in tantalum minerals valued at $22.7 million. There were no sales of tantalum carbide powder in fiscal year 2005. As of September 30, tantalum inventory sold but not shipped from the NDS included 1 t of tantalum contained in tantalum metal ingot (U.S. Department of Defense, 2005, p. 10-11, 56).

In its revised Annual Materials Plan (AMP) for fiscal year 2005 and proposed AMP for fiscal year 2006 (October 1, 2005, through September 30, 2006), the DNSC had authority to sell the following columbium and tantalum materials (actual quantity limited to remaining sales authority or inventory, with the exception of columbium concentrates): 254 t of columbium contained in columbium concentrates, 9 t of columbium contained in columbium metal ingots, 227 t of tantalum contained in tantalum minerals, 18 t of tantalum contained in tantalum metal ingots, 18 t of tantalum contained in tantalum metal powder, 9 t of tantalum contained in tantalum oxide, and 2 t of tantalum contained in tantalum carbide powder (Defense National Stockpile Center, 2005).

Production

Neither columbium nor tantalum was mined domestically in 2005. Domestic production data for ferrocolumbium are developed by the U.S. Geological Survey (USGS) from the annual voluntary domestic survey for ferroalloys. Ferrocolumbium production data for 2005, however, were incomplete at the time this report was prepared.

KEMET Corporation of Greenville, SC, the leading U.S.-based capacitor manufacturer, announced it had become the first company to market lead-free Axial Molded (T322), Radial Molded (T340) and Commercial Herm Seal (T110/T140) capacitors. This transition was driven by environmental legislation in Europe, such as end-of-life vehicle, restriction on hazardous substances, and waste electrical and electronic equipment directives aimed at eliminating lead from the manufacture of electronic components. Standard tin/lead versions of these capacitors will continue to be available (Metal-Pages,

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2005e§[1]). KEMET introduced a new high-grade, COTS (497) series of tantalum capacitors for use in such applications as industrial power supplies and military portable communications equipment with a need for more robust surge protection (Metal-Pages, 2005d§). Finally, KEMET also announced a new high-temperature (T499) tantalum chip series for use in under-hood automotive and oil exploration environments at temperatures up to 175° C (Metal-Pages, 2005f§).

Cabot Supermetals, Boyertown, PA (a business unit of Cabot Corporation, Boston, MA), announced that it would halt operations at its thin films manufacturing facility in Etna, OH, which opened in August 2004 at a cost of $12 million. Cabot cited high energy costs and weak market conditions as factors in the decision. The facility had produced tantalum-sputtering targets for use in flat-panel displays, magnetics, optics, and semiconductor applications. Cabot stated that it intended to focus on selling tantalum plate to the makers of tantalum-sputtering targets instead of producing them itself. Cabot hoped that this change in business direction would allow it to sell more tantalum and lower production costs. Cabot posted a $52 million loss in its fiscal year ending September 30, 2005, compared with a $15 million profit in fiscal year 2004 (Metal-Pages, 2005j§).

KEMET announced an agreement to buy the tantalum capacitor business of Germany's Epcos AG, which included a plant in Evora, Portugal, and some facilities in Heidenheim, Germany. KEMET intended to keep Epcos employees at the Evora plant but would stop capacitor production in Heidenheim. Heidenheim employees working in development, marketing, and sales of tantalum capacitors would be retained. The transaction was expected to be finalized in the first quarter of 2006 (Metal-Pages, 2005c§).

Consumption

Reported U.S. consumption of columbium in ferrocolumbium and nickel columbium for all end uses increased by 11% compared with that of 2004. Consumption of columbium by the steelmaking industry decreased by 4% overall, with consumption up in the carbon steel end-use category and down in the high-strength low-alloy and stainless steel end-use categories. Demand for columbium in superalloys rose to 1,220 t from 699 t, a 75% increase (table 4). Columbium in superalloys, used in the form of nickel columbium, increased to 899 t from 540 t. U.S. apparent consumption of all columbium was estimated to be 7,400 t, a 10% increase compared with that of 2004.

In 2005, estimated U.S. apparent consumption of all tantalum was 682 t, about the same as in 2004. Tantalum was consumed mostly in the form of alloys, compounds, fabricated forms, ingot, and metal powder. More than 60% of U.S. tantalum was believed to be consumed in the electronics industry, mainly in the form of tantalum capacitors. Major end-uses for tantalum capacitors included automotive electronics, pagers, personal computers, and portable telephones.

Columbium.—Columbium conducts heat and electricity well, has a high melting point (about 2,470° C), is readily fabricated, and is highly resistant to many chemical environments. Columbium in the form of ferrocolumbium is used worldwide, mostly as an alloying element in steels and in superalloys. Because of its refractory nature, appreciable amounts of columbium in the form of high-purity ferrocolumbium and nickel columbium are used in cobalt-, iron-, and nickel-base superalloys for such applications as heat-resisting and combustion equipment, jet engine components, and rocket subassemblies. Columbium carbide is used in cemented carbides to modify the properties of the cobalt-bonded, tungsten-carbide-base material to impart toughness and shock resistance. It is usually used along with carbides of other metals, such as tantalum and titanium. Columbium oxide is the intermediate product used in the manufacture of columbium carbide, columbium metal, high-purity ferrocolumbium, and nickel columbium. Acceptable substitutes, such as molybdenum, tantalum, titanium, tungsten, and vanadium, are available for some columbium applications, but substitution may lower performance and/or cost effectiveness.

Columbium was recycled mostly from products of columbium-bearing steels and superalloys; little was recovered from products specifically for their columbium content. Detailed data on the quantities of columbium recycled in 2005 are not available but may compose as much as 20% of U.S. apparent consumption of columbium (Cunningham, 2004a).

Tantalum.—The major use for tantalum as tantalum metal powder is in the production of electronic components, mainly tantalum capacitors. The tantalum capacitor exhibits reliable performance and combines compactness and high efficiency with good shelf life. Applications for tantalum capacitors include communication systems, computers, and instruments and controls for aircraft, missiles, ships, and weapon systems. Because of its high melting point (about 3,000° C), good strength at elevated temperatures, and good corrosion resistance, tantalum is combined with cobalt, iron, and nickel to produce superalloys that are used in aerospace structures and jet engine components. Tantalum carbide, which is used mostly in mixtures with carbides of such metals as columbium, titanium, and tungsten, is used in boring tools, cemented-carbide cutting tools, farm tools, and wear-resistant parts. Owing to tantalum's excellent corrosion-resistant properties, tantalum mill and fabricated products are used for corrosion- and heat-resistant chemical plant equipment, such as condensers, evaporators, heat exchangers, heating elements, and liners for pumps and reactors. Substitutes, such as aluminum, rhenium, titanium, tungsten, and zirconium, can be used in place of tantalum, but are usually used at either a performance or economic penalty.

Tantalum was recycled mostly from new scrap that was generated during the manufacture of tantalum-related electronic components and new and old scrap products of tantalum containing cemented carbides and superalloys. Detailed data on the quantities of tantalum recycled in 2005 are not available but may compose as much as 20% of U.S. apparent consumption of tantalum (Cunningham, 2004b).

Prices

Published prices for pyrochlore concentrates produced in Brazil and Canada were not available because these concentrates

[1]References that include a section mark (§) are found in the Internet References Cited section.

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were consumed internally by producers of regular-grade ferrocolumbium in Brazil and Canada and are no longer being exported. A price for Brazilian pyrochlore has not been available since 1981, and the published price for pyrochlore produced in Canada was discontinued in early 1989. The American Metal Market published price for regular-grade ferrocolumbium was discontinued in February, 2005, with the last price listed at a range of $6.45 to $6.70 per pound of contained columbium, unchanged since July 2003 (American Metal Market, 2005§). The American Metal Market published price for high-purity (vacuum-grade) ferrocolumbium was discontinued in February-March 2002 with the last price listed at a range of $17.50 to $18.00 per pound of contained columbium. The Metal Bulletin price for columbite ore, based on a minimum 65% contained columbium oxide (Nb_2O_5) and tantalum oxide (Ta_2O_5), was discontinued in October 2001 at a range of $5.50 to $7.00 per pound. According to one industry analyst, "Prices for niobium oxide, other niobium chemicals, niobium metal and various alloys derived from either pyrochlore or other niobium-bearing sources are highly variable and depend on product specifications, volume, and processing considerations" (Mosheim, 2003a).

The price for tantalum products mostly is affected by events in the supply of and demand for tantalum minerals. Yearend 2005 published prices for tantalite ore (per pound of contained Ta_2O_5) were as follows: Platts Metals Week, a range of $35 to $40, unchanged since November 2004 (Platts Metals Week, 2006); Metal Bulletin Weekly, a range of $34 to $38, unchanged since December 8, 2004 (Metal Bulletin Weekly, 2006); and Ryan's Notes, a range of $30 to $35, unchanged since August 2004 (Ryan's Notes, 2006). The Metal Bulletin published price for Greenbushes, Australia, tantalite ore was $40 per pound of contained Ta_2O_5, 40% basis, unchanged since March 2002 (Metal Bulletin Weekly, 2006). According to one industry analyst, "The pricing of tantalum chemicals, metal powders, alloys, and fabricated articles is generally established by negotiation between buyer and seller. Specifications for a particular chemical, metal powder, or fabricated article of metal or tantalum alloy are dictated by the application and its influence on processing requirements, and the volume of a specific product; all influence the prices negotiated between buyer and seller" (Mosheim, 2003b).

Based on the revised AMP for fiscal year 2006, the remaining NDS inventory of columbium metal ingots and minerals and tantalum carbide powder, metal ingots, minerals, and oxide could be exhausted in 2006. However, large inventories of tantalum materials at major processors and adequate production capacity at producers should minimize any impact on tantalum prices.

Foreign Trade

Table 5 lists columbium and tantalum export and import data. For exports, overall trade value decreased by 29%, while total gross weight increased slightly compared with those of 2004. In descending order, Israel, the Czech Republic, Germany, Kazakhstan, the United Kingdom, Mexico, Japan, France, and Thailand were the major recipients of the columbium and tantalum materials, on the basis of value, with more than 80% of the total. For imports, overall trade value decreased by 9% and total gross weight increased slightly. In descending order, Brazil, Japan, Australia, China, Kazakhstan, Germany, Thailand, and Canada were the major sources of columbium and tantalum imports, on the basis of value, with 90% of the total.

Imports for consumption of columbium ores and concentrates increased by 5 t compared with those of 2004 (table 6); imports at an assumed average grade of approximately 32% Ta_2O_5 and 30% Nb_2O_5 were estimated to contain 2.6 t of tantalum and 2.0 t of columbium. Ferrocolumbium imports rose by 5%, with Brazil accounting for 88% of the total. Brazil accounted for 72% of total value of columbium imports.

Imports for consumption of tantalum ores and concentrates were down by 16% compared with those of 2004 (table 7); imports from Australia accounted for 79% of quantity and 86% of value. Imports at an assumed average grade of approximately 37% Ta_2O_5 and 16% Nb_2O_5 were estimated to contain 379 t of tantalum and 140 t of columbium.

Brazil, which was the major source for U.S. columbium imports, accounted for 83% of the total, in units of contained columbium, and Australia, which was the major source for U.S. tantalum imports, accounted for 39% of the total, in units of contained tantalum (figures 1, 2).

Net import reliance as a percentage of apparent consumption is used to measure the adequacy of current domestic columbium and tantalum production to meet U.S. demand. For columbium in 2005, net import reliance as a percentage of apparent consumption was 100%. For tantalum, net import reliance as a percentage of apparent consumption was estimated to be 90% owing to sales by the NDS.

World Industry Structure

Principal world columbium and tantalum raw material and product producers are listed in tables 8 and 9, respectively. Annual world production of columbium and tantalum mineral concentrates, by country, is listed in table 10. Brazil and Canada were the major producers of columbium mineral concentrates, and Australia, Brazil, Canada, and Mozambique were the major producers of tantalum mineral concentrates. In addition to production reported in the annual world production table, tantalum was available from tantalum-bearing tin slags, which are byproducts from tin smelting, principally from Asia, Australia, and Brazil. However, tantalum recovery from tin slags is not a major source of tantalum.

World Review

Australia.—The administrators of Sons of Gwalia Ltd. (SOG) were expected to resolve the price dispute between SOG and Cabot in the first quarter of 2006. The West Perth firm, which went into administration in 2004, agreed to a new long-term tantalum supply contract with Cabot; however, the two firms were unable to agree on how the payment would be calculated. The method of calculation in the expired contract would result in a price substantially above current market prices for tantalum concentrate. The new contract provides for supply of tantalum

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concentrates from SOG's Wodgina Mine in Western Australia for the calendar years 2006 through 2010. SOG sells about 900 metric tons per year (t/yr) (2 million pounds per year) of tantalum oxide to Cabot and H.C. Starck Inc. (Metal-Pages, 2005a§).

Brazil.—British junior explorer Angus & Ross Plc. obtained an option to buy the license block Caicara, near Pedra Branca in the Mato Grosso State in western Brazil. Caicara has quantified tantalum reserves of 167,000 t grading 432 grams per metric ton of tantalum oxide. Angus & Ross planned confirmatory drilling in early 2006 followed by a decision possibly to build a small processing plant (Metal-Pages, 2005i§).

Companhia Brasileira de Metalurgia e Mineração (CBMM), the world's leading producer of columbium from pyrochlore, increased its capacity to produce ferrocolumbium to 54,000 t/yr with the addition of a new electric furnace in July. In October, CBMM expanded the capacity of its concentrate processing facilities to 140,000 t/yr of columbium at its plant near Araxa in Minas Gerais State. By the end of 2006, CBMM planned to expand ferrocolumbium capacity to 70,000 t/yr to meet expected increased demand from Asia (China, Japan, and the Republic of South Korea) and Europe (Tex Report, 2005§).

Canada.—In 2005, Cambior Inc.'s revenue from the production of columbium at the Niobec Mine in St. Honore, 15 km northwest of Chicoutimi, Quebec, increased by 48.6% compared with that of 2004 owing to its acquisition of the remaining 50% interest in the Niobec Mine from Sequoia Minerals Inc. in 2004. Cambior completed a mill expansion and optimization of the concentrate recovery circuit in the third quarter of 2005 that was expected to increase mine production capacity by 20%. After the expansion, the Niobec Mine, in operation since 1976, had the capacity to produce 4,000 t/yr of columbium contained in ferrocolumbium (Metal-Pages, 2005g§).

Saudi Arabia.—A representative of Tertiary Minerals Plc. announced that its wholly owned Ghurayyah columbium and tantalum project in Saudi Arabia was the world's largest deposit, with tantalum resources estimated to be 94,000 t (207 million pounds) of tantalum oxide. The pre-feasibility study was expected to be completed in 2006, and a bankable feasibility study, in 2007. If these feasibility studies are positive, Tertiary could take advantage of favorable government-secured financing in Saudi Arabia, which would limit the amount of external equity Tertiary would need to raise to 12.5%. For comparison, Tertiary estimated the tantalum resources at SOG's Greenbushes' and Wodgina's Mines to be 56,000 t and 40,000 t (124 million pounds and 89 million pounds), respectively (Metal-Pages, 2005b§).

Outlook

Columbium.—The principal use for columbium will continue to be as an additive in steelmaking, mostly in the manufacture of microalloyed steels. The production of high-strength low-alloy steel is the leading use for columbium, and the trend for columbium consumption, domestically and globally, will continue to follow closely that of steel production, as the steel industry is estimated to account for as much as 90% of columbium consumption. (Additional information about the future of the steel industry can be found in the Iron and Steel chapter of the USGS Minerals Yearbook, Volume I, Metals and Minerals.)

According to Roskill Information Services Ltd. (2005, p. 1), world-wide columbium consumption reached a record level in 2003 and grew further in 2004, inline with increased steel production. Roskill expected further expansion in 2005 and 2006. Demand for columbium, however, does not mirror trends in overall steel production, as only 10% of the total steel produced contains columbium. In addition, the geographical distribution of consumption is very uneven. In China, where the growth in steel output has been greatest, the incidence of columbium use reportedly was much lower than in Western countries. This would agree with observations of consumption of other ferroalloys per unit of steel. As a result, there is significant potential for increased demand for columbium in steel, both from growth in total steel output and also from changes in columbium composition.

The leading nonsteel use of columbium is in superalloys for, among other applications, aircraft engines. Those markets experienced a sharp fall after the terrorist attacks on September 11, 2001, resulted in an economic downturn, and the outbreak of severe acute respiratory syndrome caused travel to decline. The commercial aircraft market has since begun to recover and is expanding strongly. For instance, Boeing Company expected the airline fleet to more than double over the next 20 years, with the addition of more than 27,000 new aircraft (Boeing Company, 2006, p. 4). Nickel-base superalloys (such as alloy 718, which contains about 5% columbium) can account for about 40% to 50% of aircraft engine weight, and they are expected to be the materials of choice for the future owing to their high-temperature operating capability (Cunningham, 2004a, p. I7).

An emerging market for columbium was displacing tantalum in capacitors, owing to columbium's relatively low cost and abundant supply, but development of columbium capacitors has been slowed by technical difficulties. While there has been development of columbium capacitors that can be used in some applications, tantalum content per capacitor has decreased limiting the potential for market penetration by columbium.

Tantalum.—The main uses for tantalum are in alloys, capacitors, carbides, medical applications, and in the chemical industry, with capacitors accounting for more than 50% of consumption. Capacitors are used in digital cameras, laptops, mobile phones, video phones, and other electronic devices. The Tantalum-Niobium International Study Center expected tantalum consumption to grow by 7% per year, mainly owing to the increase in demand for capacitors. In the capacitor market segment, smaller case sizes reduced tantalum consumption per unit and tantalum lost market share to other materials, such as aluminum, ceramics, and columbium (Metal-Pages, 2005h§).

New sources of tantalum may eliminate the sharp price fluctuations of recent years (Roskill Information Services Ltd., 2005). While Australia supplied 50% of tantalum production in 2005, other significant production came from Africa, Brazil, Canada, and China, so supply was expected to be sufficient. Future supply prospects are based on reserves in Egypt, Greenland, and Saudi Arabia, and there are numerous deposits of tantalum that could be brought into production given the right market conditions. Some large projects, such as Abu Dabbab in Egypt, were already in advanced stages of development; however, future development may be keyed to depletion of Australian resources.

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An important component of world tantalum supply is the U.S. Government sales of tantalum materials from the NDS. Based on the AMP for fiscal year 2006, the NDS inventory of tantalum metal powder, ingots, and oxide could be exhausted in 2006, while the inventory of tantalum carbide powder and minerals could be exhausted in 2007. However, large inventories of tantalum materials at major processors and adequate production capacity at producers should minimize any impact on tantalum prices.

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TABLE 1
SALIENT COLUMBIUM STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Government stockpile releases, Nb content[2]	metric tons	-4	9	223	112 r	128
Production of ferrocolumbium, Nb content	do.	NA	NA	NA	NA	NA
Exports, columbium metal, compounds, alloys, gross weight	do.	NA	NA	NA	NA	NA
Imports for consumption:						
Mineral concentrates, Nb content[e]	do.	280 r	270 r	180	165	140
Columbium metal and columbium-bearing alloys, Nb content[e]	do.	1,050	673	743	940	1,380
Columbium oxide, Nb content[e]	do.	1,360	660	590	630	661
Ferrocolumbium, Nb content[e]	do.	4,480	4,030	4,080	5,170	5,430
Tin slag, Nb content	do.	NA	NA	NA	NA	NA
Consumption, Nb content:						
Raw materials	do.	NA	NA	NA	NA	NA
Ferrocolumbium and nickel columbium[e]	do.	1,300 r	2,740 r	3,220 r	3,760 r	4,170
Apparent	do.	7,090 r	5,520 r	5,600 r	6,850 r	7,400
Prices:						
Columbite[3, 4]	dollars per pound	NA	NA	NA	NA	NA
Ferrocolumbium[5]	do.	6.88	6.60	6.58	6.56	6.56
Pyrochlore[6]	do.	NA	NA	NA	NA	NA
World, production of columbium-tantalum concentrates, Nb content	metric tons	31,100	45,100 r	40,800 r	37,900 r	38,700

[e]Estimated. [r]Revised. NA Not available.

[1]Data are rounded to no more than three significant digits, except prices.

[2]Net quantity (uncommited inventory). Negative numbers indicate an increase in inventory.

[3]Yearend average value, contained pentoxides for material having a columbium pentoxide (Nb_2O_5) to tantalum pentoxide ratio of 10 to 1.

[4]The published price for columbite ore was discontinued in October 2001 at a range of $5.50 to $7.00 per pound of Nb_2O_5 content.

[5]Yearend average value of contained Nb, standard (steelmaking) grade.

[6]Yearend average value of contained pentoxide.

TABLE 2
SALIENT TANTALUM STATISTICS

		2001	2002	2003	2004	2005
United States:						
Government stockpile releases, Ta content[1]	metric tons	-53	16	335	205 r	245
Exports, gross weight:						
Tantalum ores and concentrates[2]	do.	530	232	295	717	479
Tantalum metal, compounds, alloys	do.	486	265	187	504 r	567
Tantalum and tantalum alloy powder	do.	156	188	280	257	242
Imports for consumption, Ta content:						
Mineral concentrates	do.	700 r	730 r	480 r	450	380
Tantalum metal and tantalum-bearing alloys[3]	do.	317 r	266	249	584 r	485
Tin slag	do.	NA	NA	NA	NA	NA
Consumption, Ta content:						
Raw materials	do.	NA	NA	NA	NA	NA
Apparent	do.	698 r	658 r	512 r	674 r	682
Prices, tantalite[4]	dollars per pound	37	31	28	33.5	34.5
World, production of columbium-tantalum concentrates, Ta content	metric tons	1,170 r	1,460 r	1,280	1,390 r	1,260

[r]Revised. NA Not available.

[1]Net quantity (uncommited inventory). Negative numbers indicate an increase in inventory.

[2]Includes reexports.

[3]Exclusive of waste and scrap.

[4]Yearend average value of contained pentoxides.

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TABLE 3
COLUMBIUM AND TANTALUM MATERIALS IN NATIONAL DEFENSE STOCKPILE INVENTORIES AS OF DECEMBER 31, 2005[1]

(Metric tons, columbium or tantalum content)

Material	Stockpile goal[2]	Disposal authority	Uncommitted Stockpile-grade	Uncommitted Non-stockpile-grade	Total	Committed
Columbium:						
Concentrates[e]	189		254	146	254	64
Carbide powder	--	--	--	--	--	--
Ferrocolumbium	--	--	--	--	--	--
Metal ingots[e]	19	--	9	--	9	--
Total	208	--	263	146	263	64
Tantalum:[e]						
Minerals	348		227	226	452	--
Carbide powder	6	--	2	1	3	--
Metal:						
Capacitor grade	--	--	--	--	--	--
Ingots	--	--	18	18	36	--
Oxide	9	--	9	1	10	--
Total	363	--	256	246	502	--

[e]Estimated. -- Zero.
[1]Data may not add to totals shown because of independent rounding.
[2]Goal effective as of December 28, 2001.

Source: Defense National Stockpile Center.

TABLE 4
REPORTED CONSUMPTION, BY END USE, OF FERROCOLUMBIUM AND NICKEL COLUMBIUM IN THE UNITED STATES[1]

(Metric tons, columbium content)

End use	2004	2005
Steel:		
Carbon	1,110	1,390
Stainless and heat-resisting	581 [r]	562
Full alloy	(2)	(2)
High-strength low alloy	847	464
Electric	(2) [r]	(2)
Tool	(2)	(2)
Unspecified	--	--
Total	3,060 [r]	2,950
Superalloys	699 [r]	1,220
Alloys (excluding alloy steels and superalloys)	(3)	(3)
Miscellaneous and unspecified	(4)	(4)
Grand total	3,760 [r]	4,170

[r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Included with "Steel, high-strength low alloy."
[3]Included with "Miscellaneous and unspecified."
[4]Less than ½ unit.

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TABLE 5

U.S. FOREIGN TRADE IN COLUMBIUM AND TANTALUM METAL AND ALLOYS, BY CLASS[1]

Class	2004 Gross weight (metric tons)	2004 Value (thousands)	2005 Gross weight (metric tons)	2005 Value (thousands)	Principal destinations and sources, in 2005 (gross weight in metric tons and values in thousand dollars)
Exports:[2]					
Columbium:					
Ores and concentrates	16	$108	43	$398	Germany 7, $162; United Kingdom 9, $62; Italy 3, $32; China 9, $17; Japan 3, $11.
Ferrocolumbium	294	2,920	410	4,210	Canada 322, $3,560; Mexico 81, $599; Chile 2, $27; Colombia 4, $11; Peru 1, $7.
Tantalum:					
Synthetic concentrates	6	61	66	156	Germany 2, $70; China 36, $66; Brazil 10, $13.
Ores and concentrates	717	19,300	479	9,140	Kazakhstan 287, $7,340; Brazil 168, $1,260; China 17, $375; Italy 2, $51; Taiwar[3]. $32; France 1, $17.
Unwrought, powders	257	152,000	242	112,000	Israel 81, $54,500; Czech Republic 44, $41,700; Germany 38, $5,370; Mexico 33, $5,130; Sweden 23, $2,460; Thailand 1, $1,920; Japan 4, $1,200; China 5, $648; India 3, $497.
Unwrought, alloys and metal	20	2,890	10	2,690	Belgium 4, $1,470; Japan 1, $484; Germany 1, $206; France[3], $183; Canada[3], $57; Mexico[3], $19.
Waste and scrap	321	18,600	447	21,200	United Kingdom 136, $4,150; Germany 54, $3,620; Japan 62, $3,260; Hong Kong 61, $1,120; Belgium 27, $1,050.
Wrought	162	83,400	110	49,000	Israel 19, $11,700; Germany 29, $10,300; France 111, $4,270; United Kingdom 11, $2,940; Thailand 6, $1,990; Canada 1, $245.
Total	XX	279,000	XX	199,000	Israel, $66,200; Czech Republic $41,700; Germany, $19,700; Kazahstan $7,340; United Kingdom $7,160; Mexico $5,730; Japan $4,960; France $4,470; Thailand $3,910.
Imports for consumption:					
Columbium:					
Ores and concentrates	5	41	10	117	United Kingdom 8, $67; China 1, $41; India 1, $7; Japan[3], $4.
Oxide	906	13,900	946	13,400	Brazil 420, $5,260; Estonia 208, $2,380; Germany 60, $2,410; China 104, $1,540; Russia 129, $1,460.
Ferrocolumbium	7,950	69,000	8,360	71,700	Brazil 7,400 $62,000; Canada 851, $7,800; Germany 106, $1,830.
Unwrought, alloys, metal, powder	940	18,500	1,380	26,700	Brazil 782, $13,900; Estonia 68, $2,220; Germany 58, $1,570; Belgium 14, $231; Kazakhstan 3, $204; China 9, $177.
Tantalum:					
Synthetic concentrates	--	--	--	--	All from China.
Ores and concentrates	1,480	58,000	1,250	43,700	Australia 982, $37,840; Canada 268, $5,930; United Kingdom[3], $4.
Unwrought powders	386	98,400	232	63,100	Japan 50, $25,600; China 77, $13,400; Germany 48, $11,600; Thailand 49, $11,300.
Unwrought, alloys and metal	166	19,200	174	24,700	Kazakhstan 89, $12,700; Japan 9, $10,900; China 24, $3,480; Germany 8, $1,730; United Kingdom 5, $433; Hong Kong 6, $404.
Waste and scrap	503	20,500	758	17,500	China 345, $2,570; Japan 101, $2,240; Israel 44, $2,100; Germany 33, $1,540; Hong Kong 28, $1,100; Netherlands 22, $669; Taiwan 10, $171.
Wrought	38	10,000	78	17,100	China 21, $8,290; Kazakhstan 47, $6,990; Canada 1, $419; Japan 6, $594; Germany 1, $321; Austria 1, $159; Russia 1, $103.
Total	XX	307,000	XX	278,000	Brazil $74,100; Japan $39,330; Australia $37,800; China $30,123; Kazakhstan $19,900; Germany $16,900; Thailand $11,270; Canada $9,740.

XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]For columbium, data on exports of metal and alloys in unwrought and wrought form, including waste and scrap, are not available; included in nonspecific tariff classification.

[3]Less than ½ unit.

Sources: U.S. Census Bureau and U.S. Geological Survey.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF COLUMBIUM ORES AND CONCENTRATES, BY COUNTRY[1]

Country	2004		2005	
	Gross weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Value (thousands)
Australia	4	$6	--	--
Canada	(2)	4	--	--
China	1	30	1	$41
India	--	--	1	7
Japan	--	--	(2)	4
United Kingdom	--	--	8	67
Total	5	41	10	119

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 7
U.S IMPORTS FOR CONSUMPTION OF TANTALUM ORES AND CONCENTRATES, BY COUNTRY[1]

Country	2004		2005	
	Gross weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Value (thousands)
Australia	1,170	$52,100	982	$37,800
Canada	277	4,570	268	5,930
China	(2)	4	(2)	3
Ethiopia	30	1,240	--	--
Japan	(2)	30	--	--
United Kingdom	1	30	(2)	2
Total	1,480	58,000 r	1,250	43,700

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Sources: U.S. Census Bureau and U.S. Geological Survey.

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TABLE 8
PRINCIPAL WORLD COLUMBIUM AND TANTALUM RAW MATERIAL PRODUCERS

Country	Company and/or mine	Material type
Mining of columbium- and tantalum-bearing ores:		
Australia	Sons of Gwalia Ltd. (Greenbushes)	Columbium-tantalum.
Do.	Sons of Gwalia Ltd. (Wodgina)	Tantalum.
Brazil	Cia. Brasileira de Metalurgia e Mineracao (Araxa)	Columbium.
Do.	Cia. de Estanho Minas Brasil[1]	Columbium-tantalum.
Do.	Paranapanema S.A. Mineracao Industria e Construcao (Pitinga)	Do.
Do.	Mineracao Catalao de Goias S.A. (Catalao)	Columbium.
Canada	Cambior Inc. and Mazarin Inc. (Niobec)	Do.
Do.	Tantalum Mining Corp. of Canada Ltd.[2]	Tantalum.
China	Government-owned	Columbium-tantalum.
Production of columbium- and tantalum-bearing tin slags:		
Australia	Sons of Gwalia Ltd. (Greenbushes)	Do.
Brazil	Cia. Industrial Fluminense[1]	Do.
Do.	Mamoré Mineracao e Metalurgia[3]	Do.
Thailand	Thailand Smelting and Refining Co. Ltd.	Do.
Production capacity for columbium- and tantalum-bearing synthetic concentrates, Germany, western states	H.C. Starck GmbH & Co. KG	Do.

[1]A wholly owned subsidiary of Metallurg Inc., New York, NY.
[2]A wholly owned subsidiary of Cabot Corp.
[3]A subsidiary of Paranapanema S.A. Mineracao Indústria e Construcao.

TABLE 9
PRINCIPAL WORLD PRODUCERS OF COLUMBIUM AND TANTALUM PRODUCTS

Country	Company	Products[1]
Austria	Treibacher Industrie AG	Nb and Ta oxide/carbide, FeNb, and NiNb.
Brazil	Cia. Brasileira de Metalurgia e Mineracao	Nb oxide/metal, FeNb, and NiNb.
Do.	Cia. Industrial Fluminense[2]	Nb and Ta oxide.
Do.	Mineracao Catalao de Goias S.A.	FeNb.
Canada	Cambior Inc. and Mazarin Inc.	Do.
Estonia	Silmet	Nb oxide/metal.
Germany, western states	Gesellschaft fur Elektrometallurgie mbH[2]	FeNb and NiNb.
Do.	H.C. Starck GmbH & Co. KG	Nb and Ta oxide/metal/carbide, K-salt, FeNb, NiNb, and Ta capacitor powder.
Japan	Mitsui Mining & Smelting Co.	Nb and Ta oxide/metal/carbide.
Do.	Cabot Supermetals[3]	Ta capacitor powder.
Do.	H.C. Starck-V Tech Ltd.[4]	Do.
Kazakhstan	Ulba Metallurgical	Ta oxide/metal.
Do.	Irtysh Chemical & Metallurgical Works	Nb oxide/metal.
Russia	Solikamsk Magnesium Works	Nb and Ta oxide.
Thailand	H.C. Starck (Thailand) Co. Ltd.[4]	K-salt and Ta metal.
United States	Cabot Supermetals[3]	Nb and Ta oxide/metal, K-salt, and Ta capacitor powder.
Do.	H.C. Starck Inc.[5]	Nb and Ta metal, and Ta capacitor powder.
Do.	Kennametal Inc.	Nb and Ta carbide.
Do.	Reading Alloys Inc.	FeNb and NiNb.
Do.	Wah Chang[6]	Nb metal and FeNb.

[1]Nb, columbium; Ta, tantalum; FeNb, ferrocolumbium; NiNb, nickel columbium; K-salt, potassium fluotantalate; oxide, pentoxide.
[2]A wholly owned subsidiary of Metallurg Inc., New York, NY.
[3]A wholly owned subsidiary of Cabot Corp.
[4]A subsidiary of H.C. Starck GmbH & Co. KG.
[5]Jointly owned by Bayer Corp. and H.C. Starck GmbH & Co. KG.
[6]A subsidiary of Allegheny Technologies Inc.

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TABLE 10

COLUMBIUM AND TANTALUM: ESTIMATED WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY[1, 2]

(Metric tons)

Country[5]	Gross weight[3]					Columbium content[4]					Tantalum content[4]				
	2001	2002	2003	2004	2005	2001	2002	2003	2004	2005	2001	2002	2003	2004	2005
Australia, columbite-tantalite	2,220	3,100	2,500	2,000	2,000	230	290	230	200	200	660	940	765	730	730
Brazil:															
Pyrochlore	65,000	68,800	69,000	56,100	56,200 p	27,300	41,300 r	37,000 r	34,000 r	35,000 p	(6) r	(6) r	(6) r	(6) r	(6) p
Tantalite	750	680	715	720	730 p	(6) r	(6) r	(6) r	(6) r	(6)	210	190	200	250	250 p
Burundi	123 7	72 7	24 7	23 r, 7	24	NA	NA	4 r	4 r	4	32	15	6	6	6
Canada:															
Pyrochlore	7,070	7,410	7,270	7,300 7	7,300	3,180	3,330	3,270 7	3,450 7	3,300 p	(6) r	(6) r	(6) r	(6) r	(6)
Tantalite	308	232	220	220 7	220 p	15	12	11 7	10 7	10 p	77	58	55	69 7	70 p
Congo (Kinshasa), columbite-tantalite	200	100	50	50 r, 7	50	60 r	30 r	25 r	25 r	25	60	30	25 r	25 r	25
Ethiopia, tantalite	47 7	55 7	58 r, 7	71 r, 7	71	5	6	6	7 r	7	28	33 r	35	45 r	45
Mozambique	27 7	47 7	189 7	712 7	281	3 r	6 r	23 r	87 r	34	8 r	13 r	54 r	205 r	81
Namibia	5	9	23 r, 7	10 r, 7	5	(6)	(6)	1 7	1 7	(6)	3	5 r	14 r	6 r	3
Nigeria, columbite-tantalite	610	156 7	383 4	100 r, 7	100	250	65	160	40 r	40	30	8	21	5 r	5
Rwanda	241 7	96 7	128 7	200	200	76	30	40	63	63	53	20	26	40	40
Uganda	11 7	6 7	16 7	(6) 7	(6)	5	3 7	8	(6) r	(6)	3 7	2 7	4 7	(6) 7	(6)
Zimbabwe	30	481 7	231 7	14	NA	NA	NA	NA	NA	NA	9	144	69	4	NA
Total	76,600	81,200	80,800	67,500	67,200	31,100	45,100 r	40,800 r	37,900 r	38,700	1,170 r	1,460 r	1,280	1,390 r	1,260

rRevised. NA Not available.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Excludes production of columbium and tantalum contained in tin ores and slags. Table includes data available through July 9, 2006.

[3]Data on gross weight generally have been presented as reported in official sources of the respective countries, divided into concentrates of columbite, tantalite, and pyrochlore where information is available to do so, and reported in groups, such as columbite and tantalite, where it is not.

[4]Unless otherwise specified, data presented for metal content are estimates based on, in most part, reported gross weight and/or pentoxide content.

[5]In addition to the countries listed, Bolivia, China, French Guiana, Kazakhstan, and Russia also produce, or are believed to produce, columbium and tantalum mineral concentrates, but available information is inadequate to make reliable estimates of output levels.

[6]Less than ½ unit.

[7]Reported figure.

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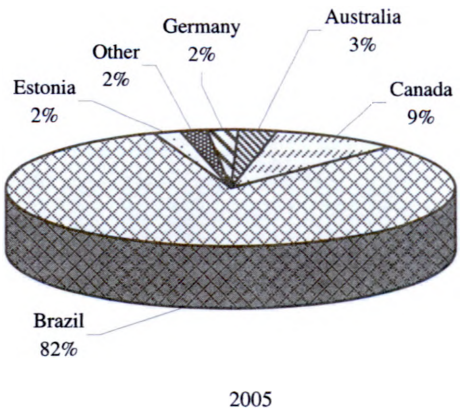
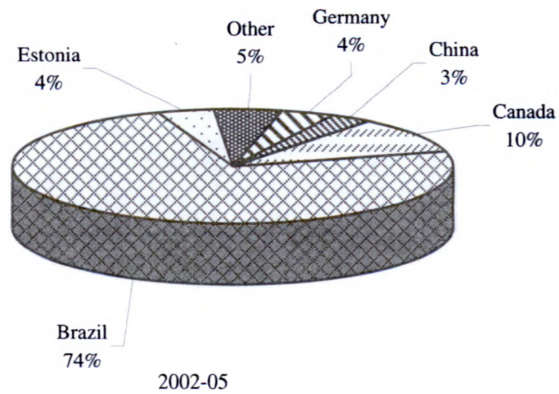
FIGURE 1
MAJOR SOURCES OF U.S. COLUMBIUM IMPORTS

(Columbium content)[1]



2005

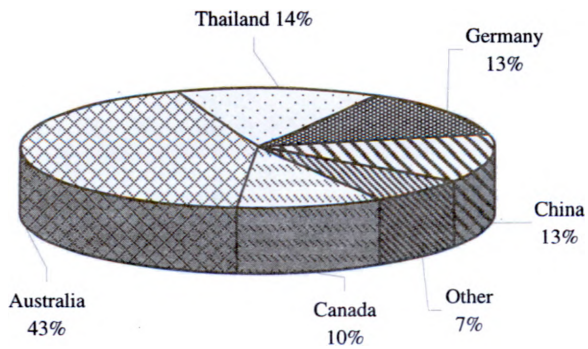


2002-05

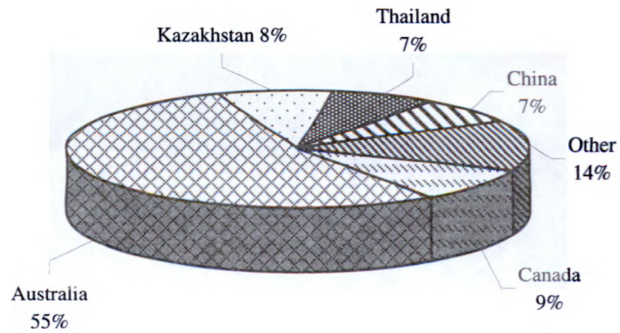
[e]Estimated.

FIGURE 2
MAJOR SOURCES OF U.S. TANTALUM IMPORTS

(Tantalum content)[1]



2005



2002-05

[e]Estimated.

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COPPER

By Daniel L. Edelstein

Domestic survey data and tables were prepared by Mohamed M. Mohamed, Nicholas A. Muniz, and Wanda G. Wooten, statistical assistants, and the world production tables were prepared by Regina R. Coleman and Glenn J. Wallace, international data coordinators.

In the United States, mine production of recoverable copper in 2005 declined by 20,000 metric tons (t) (1%) to 1.140 million metric tons (Mt) primarily owing to a 16-week strike that sharply curtailed production by a major producer. Downstream, U.S. smelter and refinery production declined by 3.5% and 4%, respectively, in part owing to increased exports of copper in concentrates. Equipment and labor shortages also delayed expansions and startup of new operations. Electrowon production of refined copper from the leaching of copper ores, which declined for the fourth consecutive year, fell by 30,000 t and accounted for 49% of mine output and 44% of refined copper production. Reported domestic consumption of refined copper in 2005 fell by 6% to 2.27 Mt and was at its lowest level since 2001.

Global mine production of copper in 2005 rose for the second consecutive year, increasing by 350,000 t (2.4%) to a record-high 15.1 Mt. Owing to production shortfalls in the United States and South America, however, global mine production fell short of its anticipated growth, and mine capacity utilization fell to its lowest level in recent years. The United States accounted for 8% of world production and narrowly retained its position as the world's second ranked mine producer. Chile, where mine production declined by 90,000 t (2%), remained the leading mine producer and accounted for more than 35% of total world production. Global smelter and refinery production rose by 5% and 4%, respectively. The United States fell to seventh place behind India in world smelter production and remained fourth in refinery output behind Chile, China, and Japan.

Global consumption of refined copper fell by 140,000 t (1%) (International Copper Study Group, 2006a, p. 19-20). Strong growth in Asia from China and India was more than offset by reduced use by other significant consuming regions. China, where apparent consumption of refined copper grew by 8%, remained the world's leading consumer of refined copper with an estimated 22% market share.

Copper prices trended upward throughout the year, and by yearend, the COMEX (COMEX Division of the New York Mercantile Exchange) spot price reached a record-high value of more than $2.00 per pound of copper. Production of refined copper was insufficient to meet global demand, and the refined copper production deficit that had developed during the preceding 2 years continued through most of 2005. Estimated global inventories of refined copper continued their downward trend and were down by 70,000 t at yearend (International Copper Study Group, 2006a, p. 21). This shortfall happened despite the growth in world production of refined copper and the decline in refined copper consumption.

The U.S. Geological Survey estimated that world copper reserves were 480 Mt and that the world copper reserve base was 940 Mt. The United States had 7% each of the world's copper reserves and reserve base. A recent assessment of U.S. copper resources indicated 550 Mt of copper in identified (260 Mt) and undiscovered resources (290 Mt), more than double the previous estimate (U.S. Geological Survey National Mineral Resource Assessment Team, 2000, p. 14). Similarly, a preliminary assessment of global copper resources indicated that global land-based resources exceed 3 billion metric tons, about double the previously published estimate.

The principal mining States for copper, which in descending order of production were Arizona, Utah, New Mexico, Nevada, and Montana, accounted for 99% of domestic production; copper was also recovered at mines in Idaho, Missouri, and Nevada. Although copper was recovered at 24 mines that operated in the United States, 14 mines accounted for more than 99% of production. The remaining 10 mines were either small leach operations or byproduct producers of copper.

During the year, 3 primary smelters, 4 electrolytic and 3 fire refineries, and 13 solvent extraction-electrowinning (SX-EW) facilities operated in the United States. The three fire refineries processed scrap to recover unalloyed copper products. Scrap was also consumed in relatively small quantities at several of the primary smelters. U.S. smelter and refinery capacity remained essentially unchanged at approximately 900,000 t and 2.25 Mt, respectively, and capacity utilization fell to 58% and 57%, respectively. Included in 2005 smelter capacity was Phelps Dodge Corp.'s (Phoenix, AZ) 190,000-metric-ton-per-year (t/yr) Hurley, NM, smelter. The smelter had been retained in care-and-maintenance status since closing in 2001, but in October 2005 the company announced that it was closing permanently and being dismantled.

In 2005, copper recovered from refined or remelted scrap (80% from new scrap and 20% from old scrap) composed 30% of the total U.S. copper supply. The conversion of old scrap to alloys and refined copper fell by 5% to 182,000 t of recoverable copper. The quantity of copper recovered from new scrap (769,000 t) was essentially unchanged from that of the previous year. Copper was consumed as refined copper and as direct melt scrap at approximately 30 brass mills, 14 wire-rod mills, and 500 chemical plants, foundries, and miscellaneous operations.

Owing to sustained low capacity utilization at U.S. refineries, the net import reliance for refined copper as a percentage of apparent consumption (42%) remained close to the record-high level of 43% in 2004. Imports of refined copper rose by approximately 200,000 t to 1 Mt of refined copper; Chile, Canada, and Peru, in decreasing order, accounted for 88% of refined copper imports. Despite lower domestic consumption, the rise in imports reflected lower copper inventory levels from which to draw. Domestic inventories, which had declined by 522,000 t in 2004, declined by only 68,000 t in 2005.

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Legislation and Government Programs

In 2003, the U.S. Environmental Protection Agency (EPA), as part of its review of existing drinking water standards for 69 substances (including lead and copper) for which national primary drinking water regulations were established prior to 1997, affirmed its conclusion that the established maximum contaminant level goal for copper of 1.3 milligrams per liter should be retained pending collection of additional data on health risks. Owing to high-profile incidences of elevated drinking water lead levels in the District of Columbia, the EPA initiated a national review and held a series of workshops in 2004 to discuss issues associated with implementation of the lead and copper rule. As a result of the review and workshops, the EPA released a drinking water lead reduction plan in March 2005 that identified nine actions to improve implementation of the rule. In 2006, these actions were consolidated into seven proposed changes aimed at reducing public exposure to lead in drinking water. While copper levels were not targeted, several actions, including the advance notification and approval of changes to water treatment that could affect a water system's corrosion control and proposed timelines for allowing plumbing replacement as a treatment option for reducing lead or copper levels, could affect the use of copper and copper alloys in water supply markets (U.S. Environmental Protection Agency, 2006).

On April 1, the Import Administration, International Trade Administration, U.S. Department of Commerce, initiated expedited sunset reviews of the antidumping and countervailing duty orders against brass sheet and strip from several countries including Brazil, Canada, France, Italy, and Japan. The material was classified under codes 7409.21.00 and 7409.29.00 of the Harmonized Tariff Schedule of the United States. In all cases, the U.S. Department of Commerce found that revocation of duties would likely lead to recurrence of dumping or countervailing subsidy (U.S. Department of Commerce, 2005a, b).

Production

Mine production in the United States declined slightly in 2005 despite expectations of higher output held at yearend 2004. On July 2, workers at ASARCO Incorporated's (Asarco) (Phoenix, AZ) mines and facilities began a strike that lasted 16 weeks and sharply curtailed mine output. Unusually heavy rains in parts of Arizona in the first half of the year reduced SX-EW output, and equipment and labor shortages throughout the industry delayed expansions and mine startups. Quadra Mining Ltd. (Vancouver, British Columbia, Canada) reported that slope stability problems at the Tripp-Veteran pit (Robinson Mine, NV) forced the company to divert equipment to deweight a section of pit wall and to switch some production to lower grade and more metallurgically difficult ore that Quadra had not planned on mining until the first quarter of 2006. This reduced anticipated annual production by approximately 7,000 t of copper in concentrate (Quadra Mining, Ltd., 2005).

Downstream copper smelter and refinery production declined owing to the Asarco strike, shutdown of Asarco's smelter in Hayden, AZ, in October for repairs, and reduced SX-EW production, which in part resulted from dilution of leach solutions from heavy rains. Three primary smelters and four primary electrolytic refineries operated during 2005. The Miami electrolytic refinery in Arizona and the Chino smelter in New Mexico that closed in 2002 were retained on care-and-maintenance status until their official closure in October (Phelps Dodge Corp., 2005).

Company Reviews.—On July 2, workers at Asarco's Ray Mine in Arizona began a strike that soon spread to its other Arizona facilities (Hayden smelter and Mission and Silver Bell Mines) and its Amarillo, TX, refinery. The strike followed expiration of the contract between Asarco and the United Steelworkers Union at Ray. Prior to the strike, workers at Asarco's other facilities had continued to work under the terms of a previous contract that had expired in July 2004. On July 13, Asarco declared a force majeure on all outbound refined copper products from its Amarillo complex, including wire rod. Asarco was wholly owned by Grupo Mexico, S.A. de C.V. (Mexico City, Mexico) through its subsidiary, Americas Mining Corp. (Barry, 2005b, c; Brooks, 2005).

The strike by about 1,500 Asarco workers remained unsettled when Asarco filed for Chapter 11 bankruptcy protection from creditors on August 10. Grupo Mexico cited high production costs, high environmental and asbestos liabilities, and the prolonged general strike as the reasons for the filing. Owing to the need for increased stripping and the highest rainfall in 10 years at the Ray Mine, Asarco's break-even cash costs rose to $1.14 per pound of copper in 2005, up from $0.95 per pound in the second quarter of 2004. Analysts estimated that Asarco's environmental liabilities could exceed $1.9 billion (Barry, 2005d; Grupo Mexico, S.A. de C.V., 2005, p. 9; Millman, 2005; Platts Metals Week, 2005c; ASARCO LLC, undated §[1])

Workers at Asarco voted on November 12-13 to end their strike, though ramp-up to full production was not expected until February 2006. The new contract extended the terms of their existing contract through the end of 2006 but included a successorship clause that required any buyer of Asarco to recognize and negotiate with the union (Barry, 2005§). Grupo Mexico reported mine production, through bankruptcy filing, of 53,700 t of copper in concentrate and 32,700 t of electrowon copper and total refined production of 80,000 t (Grupo Mexico, S.A. de C.V., 2006, p. 13-14). Full-year 2005 cathode production was projected to be 150,000 t, down from a prestrike projection of 220,000 t (Barry, 2005a).

Copper production from BHP Billiton's (Melbourne, Australia) and residual Arizona leach operations at Miami and Pinto Valley totaled 8,800 t in 2005, down from 9,500 t in 2004 (BHP Billiton, 2006, p. 16). In January, Resolution Copper Company [owned 55% by Rio Tinto plc (London, United Kingdom) and 45% by BHP Billiton] announced that it would resume its drilling program as part of a comprehensive 5-year, $200 million feasibility study aimed at providing necessary data to plan for construction of the project. Resolution was formed to evaluate a large copper sulfide deposit located at a depth of approximately 2 kilometers (km) below the surface beneath BHP Billiton's shuttered Magma Mine, which operated from 1912 through 1996 in the Pioneer mining district east of

[1]References that include a section mark (§) are found in the Internet References Cited section.

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Superior, AZ. If mine development were to proceed, Rio Tinto didn't anticipate production prior to 2014 (Resolution Copper Company, 2005).

Constellation Copper Corp. (Denver, CO) announced that it began applying acid solution to its leach dumps at its Lisbon Valley Mine in Utah on December 19. Startup of SX-EW cathode had been anticipated during the fourth quarter of the year, but completion of the SX-EW facilities had been delayed by a shortage of pipefitters, and construction was not completed until mid-January 2006, with the first cathode produced later during the first quarter. By mid-October 2005, mining of ore had reached its projected capacity of 24,000 metric tons per day (t/d). In May, Constellation announced that it had discovered an additional copper deposit at the Flying Diamond exploration target and additional drilling continued through the year (Constellation Copper Corp., 2005a, b; 2006).

Nord Resources Corporation (Dragoon, AZ) continued working toward reopening of its Johnson Camp Mine located in southern Arizona, which last produced in August 2003. In January, Nord completed the purchase of a crusher and, in October, completed an update of the 2000 feasibility study. In order to resume full mining operations, Nord anticipated a capital requirement in excess of $22 million during its first 2 years of operation for rehabilitation and expansion of facilities and installation of crushing and conveying equipment. Restart was subject to obtaining the necessary financing and mining permits. Operations at Johnson Camp would involve removal of 4,500 t/d of overburden and mining about 8,000 t/d of ore to produce about 9,000 t/yr of electrowon cathode (Nord Resources Corp., 2006).

In 2005, Phelps Dodge reported copper production of 1.17 Mt, which included minority participants' share of 223,000 t, from its worldwide operations, compared with 1.20 Mt and 220,000 t, respectively, in 2004. U.S. production in 2005 was 671,000 t of copper (515,000 t electrowon and 168,000 t in concentrate), a decrease of 13,000 t from that in 2004 (Phelps Dodge Corp., 2006, p. 9).

Production of electrowon copper at the Morenci Mine complex in Arizona of 363,000 t was down by 18,000 t. The complex comprised an open pit, a concentrator, four solvent extraction (SX) facilities, and three electrowinning tankhouses. In June, Phelps Dodge announced that it would spend $210 million to construct the first-ever commercial-scale copper concentrate leaching and direct electrowinning facility at Morenci. The facility would employ proprietary pressure leaching technology developed by Phelps Dodge and under demonstration at the Bagdad Mine in Arizona to process copper ores containing a mix of primary and secondary copper sulfide minerals. Restart of the idled Morenci concentrator was included in the cost and project development. The new concentrate leaching facilities were to be incorporated into the existing leaching and electrowinning complex at Morenci. Concentrate leach production, slated for startup in 2007, would replace an expected decline in Morenci's heap leach output later in this decade. The actions at Morenci affected plans for several other Phelps Dodge facilities in Arizona and New Mexico, including the Miami refinery in Arizona, the Chino smelter in New Mexico, and the Tyrone and Cobre Mines in New Mexico. The affected assets were determined by Phelps Dodge to be "impaired," and the idled Chino smelter and Miami refinery were permanently closed (Phelps Dodge Corp., 2005).

Production at the Bagdad Mine in Arizona declined to 91,300 t (76,900 t in net concentrate production and 14,300 t electrowon) from 99,900 t of copper in 2004. Electrowon production was reduced in part by a temporary conversion in May (7-month duration) of the high-temperature concentrate pressure-leaching demonstration plant to medium temperatures to test an alternative technology that consumes less acid and oxygen (Phelps Dodge Corp., 2006, p. 13).

At the Sierrita Mine in Arizona, copper production rose by about 2,000 t to reach 80,000 t. Electrowon production rose to 6,800 t. The electrowinning tankhouse had been shuttered during much of 2004 owing to expiration of its land lease that was subsequently renewed. In early 2006, production began at a new 18,000-t/yr copper sulfate plant (Phelps Dodge Corp., 2006, p. 3).

At the Chino Mine in New Mexico, the sulfide ore mill operated at 80% of capacity throughout the year, and production rose to 46,000 t from 27,000 t in 2004. Electrowon production fell to 49,000 t from 56,000 t in 2004 owing to lower ore grade and reduced placement of ore on leach stockpiles. Though rehabilitation work continued in the first half of the year at the Cobre Mine, based on higher estimated restart and operating costs from its decision to permanently close the Chino smelter, Phelps Dodge claimed a $59.9 million pretax impairment charge against Cobre in June. Phelps Dodge reclassified most of Cobre's millable reserves as leach reserves because new mine plans excluded reopening the mill. At the Tyrone Mine, production of electrowon copper fell to 36,700 t from 39,000 t in 2004. Phelps Dodge focused on reclaiming stockpiles around the perimeter of the property, which effectively increased operating costs while reducing reserves by 14% (Phelps Dodge Corp, 2006, p. 3-15).

At Miami, AZ, Phelps Dodges's electrowon production rose to 11,200 t of copper from 8,900 t in 2004. Mining of leach material, which happened last in 2001, remained suspended, though Phelps Dodge reported Miami reserves to be 102,000 t of leach ore grading 0.37% copper. Production of refined copper at its El Paso, TX, refinery declined to 267,000 t from 280,000 t in 2004, well below its capacity of about 410,000 t (Phelps Dodge Corp., 2006, p. 3-11).

Robinson Nevada Mining Company (RNMC) (a wholly owned subsidiary of Quadra Mining Ltd.,Vancouver, British Columbia, Canada), produced 227,000 t of copper concentrate containing 57,200 t of copper during its first full year of operation from the Tripp area of the Tripp-Veteran pit at the Robinson Mine. Though in 2004 it contracted with Washington Group International (Boise, ID) to conduct its mining operations, by yearend 2005, RNMC had assumed control of mining operations. Total reported cash costs of $1.16 per pound of copper were higher than anticipated owing to lower head grades, lower than anticipated recoveries, and higher smelting and utility costs. The stripping ratio (ore:waste), which averaged 4.0 for the year, increased throughout the year as the company worked to expose ore in the Veteran area of the pit. At yearend, proven and probable reserves had increased to more than 145 Mt of ore grading 0.69% copper and 0.25 grams per metric ton (g/t) gold (Quadra Mining Ltd., 2006, p. 1-7).

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During the fourth quarter of 2005, Quadra completed the acquisition of the Carlota project in the Globe/Miami mining district in Arizona from Cambior Inc. (Longueuil, Quebec, Canada) for an aggregate of about $23 million. Carlota was projected to be an open-pit leach operation with an 11-year mine life and an average production rate of about 30,000 t/yr of copper (Quadra Mining Ltd., 2006, p. 7).

At Rio Tinto's Bingham Canyon Mine in Utah, production of copper in concentrate fell by 16% to 221,000 t despite slightly higher mill throughput. Copper mill-head grade declined to 0.53% copper from 0.63% copper in 2004 owing to optimization of mine production in favor of molybdenum. Average molybdenum grades nearly doubled to 0.058% molybdenum from 0.033% in 2004. Smelter and refinery production, however, fell by only 4% and 6% to 229,000 t and 232,000 t, respectively, owing to the processing of stockpiled concentrates and a 2-week smelter maintenance shutdown that had reduced production during the fourth quarter of 2004 (Rio Tinto plc., 2005a, p. 16; 2005b, p. 14).

Consumption

Despite a 5% increase in reported consumption in 2004, a downturn in the market that developed in the fourth quarter of the year continued into 2005, and reported domestic consumption of refined copper in 2005 plummeted by 6% to the lowest level since 1992. While U.S. production and shipments of wire rod declined by 8% and 7%, respectively, apparent consumption (domestic shipments plus net trade) rose slightly to 1.9 Mt. Net imports of wire rod more than doubled to 220,000 t and accounted for 12% of apparent consumption (American Bureau of Metal Statistics, Inc., 2006b). Despite a strong fourth quarter finish, brass mill product shipments by domestic producers declined nominally in 2005 to 770,000 t from 780,000 t in 2004. The copper tube market, which rose to 282,000 t from 276,000 t in 2004, was the only market segment to show a significant increase (American Bureau of Metal Statistics, Inc., 2006a).

The estimated total supply of copper and copper-alloy products to the U.S. market by fabricators (brass mills, wire mills, foundries, and powder producers), which included net imports, declined by 6% in 2005 from that in 2004 and was at about the same level as in 2003. Brass mill products accounted for 50% of total shipments to the domestic market; wire mill products, 48%; and foundry and powder products, 2%. In building construction, which was the leading end-use sector, total mill shipments declined by 9% and accounted for 49% of the market. Building construction included products used for air conditioning, architectural applications, builder's hardware, building wire, commercial refrigeration, and plumbing and heating. Shipments for electric/electronic products (20% market share), consumer and general products (11% market share), transportation equipment (11% marketshare), and industrial machinery (9% market share) declined by 3%, 5%, 5%, and 2%, respectively (Copper Development Association, Inc., 2006, p. 18-21).

Prices and Stocks

Following a sharp rise in prices at yearend 2004, the COMEX price having peaked at $1.54 per pound of copper on December 28, copper prices moderated slightly during the first quarter of the year with the COMEX price averaging about $1.47 per pound for the first quarter. Copper prices renewed their upward trend in April, when the COMEX price averaged $1.49 per pound, the highest monthly average since January 1989. In March and April, the London Metal Exchange Ltd. (LME) spot price premium over the COMEX price averaged 4.6 cents per pound and 4.0 cents per pound, respectively. This uncharacteristically large spread was last seen briefly in 1996 and compared with an average premium of only about 1 cent per pound in 2004. World commodity exchange stock levels during both periods of high price differential were at extremely low levels by historical standards. In 1996, exchange inventories fell to below 200,000 t, from a peak of almost 700,000 t in 1993, and by the end of March 2005, exchange stocks had fallen to approximately 100,000 t from 1.3 Mt in 2002.

Copper began a more precipitous rise during the third quarter of the year. With copper inventories at minimal levels, copper prices became extremely sensitive to announced production disruptions. Production disruptions in the United States, including the Asarco strike, pitwall problems at the Robinson Mine, and reduced production at the Bingham Canyon Mine, as well as global disruptions, such as a week-long strike at the beginning of July at the 140,000 t/yr-of-copper Zaldivar Mine in Chile helped to stimulate the midyear price rise (Placer-Dome Inc., 2005).

During the fourth quarter of the year, copper prices continued to move upward to successive record-high levels. The COMEX price averaged $2.01 per pound of copper in November and $2.17 per pound in December, closing the year at $2.16 per pound. A particularly tight U.S. market for copper led to an increasing spread between LME and COMEX prices, which averaged $0.10 per pound in December. The price rise was in part fueled by speculation in mid-November that a trader acting on behalf of China's State Reserve Bureau (SRB) had built a substantial short position by selling forward copper contracts containing an estimated 100,000 to 200,000 t of copper on the LME and that releases totaling about 60,000 t of copper from SRB stockpiles over the preceding months were intended to ease supply constraints and lower copper prices (Platts Metals Week, 2005a). The reported December expiration date for the forward contracts came and went without disruption, and speculation was that the initial SRB short position had been overestimated (Bresnick, 2005§).

Copper scrap prices generally followed the upward trend in refined copper prices. With higher refined prices, however, the discount of most grades of copper scrap to refined copper increased. The American Metal Market average price discount for refiners No. 2 scrap rose to 31 cents per pound from 21 cents per pound in 2004 and 11 cents per pound in 2003, and the discount for brass mill No. 1 scrap rose to 15 cents per pound from about 3 cents per pound in 2004.

Trade

With limited exchange stocks to draw upon, the shortfall in domestic copper production relative to demand was satisfied by an increase in imports of refined copper. Net refined copper

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imports in 2005 rose to 961,000 t from 689,000 t in 2004. U.S. net import reliance as a percentage of apparent consumption, which includes copper recovered from old scrap, declined to 42% from the record-high 43% in 2004. Chile was the leading source of unwrought copper products from 2001 through 2005 and accounted for 34% of unmanufactured imports, followed by Canada (33%) and Peru (19%). Refined copper accounted for 78% of unwrought copper imports during the same period. The U.S. Census Bureau reported that exports of contained copper in concentrates rose to 147,000 t in 2005 from 24,000 t in 2004. Though an increase was anticipated from a full-year of operation of both the Robinson Mine and the Continental Pit in Montana, the balance between U.S. concentrate production and U.S. smelter production indicates that it is likely that Census Bureau data overstated the copper content of exports, tabulating some data on a gross weight basis instead of the purported copper basis.

U.S. Census Bureau data compiled by the Copper and Brass Fabricators Council Inc. (2006, p. 1-9) indicate that imports of 286,000 t of copper and copper-alloy semifabricated products (excluding wire-rod mill products) were down by 12% from those of the previous year, and exports rose to 164,000 t from 143,000 t in 2004. Consequently, net imports declined to 122,000 t in 2005 from 184,000 t in 2004. In 2005, Canada and Mexico collectively accounted for 71% of semifabricated copper exports and 28% of imports.

Exports of copper scrap for 2004 totaled 643,000 t, down from 714,000 t in 2004. China (including Hong Kong) was the destination for 61% of domestic scrap exports and accounted for 71% of reported global scrap imports. The United States remained the leading source of scrap, accounting for 17% of reported global scrap exports. However, there is a large discrepancy between reported global exports of scrap (3.76 Mt) and reported imports (7.0 Mt) (International Copper Study Group, 2006a, p. 41-44).

In 2004, the U.S. Census Bureau reported that the value of Russian wire-rod imports totaled $132 million and therefore exceeded the threshold limit of $115 million allowable under the Generalized System of Preferences (GSP). As a result, wire-rod imports from Russia lost their duty-free status effective July 1, 2005, and were then subject to a 3% ad valorem tariff. In 2003, Russia had been the second ranked source of wire-rod imports in to the United States, behind Canada but fell to third behind Mexico in 2004. Despite the loss of duty-free status, imports of wire rod from Russia rose to 102,000 t in 2005 from 29,000 t in 2004.

Russian export tariffs favored the export of value-added products, resulting in greater domestic consumption of refined copper and an increase in exports of copper and copper-alloy semifabricates, which rose to 350,000 t in 2005 from only 59,000 t in 2001, while Russian exports of refined copper fell to 301,000 t in 2005 from 585,000 t in 2001.

World Industry Structure

While world production of refined copper rose to 16.6 Mt, an increase of 700,000 t from that in 2004, world copper use declined by 1% to 16.63 Mt (International Copper Study Group, 2006a, p. 19). The combined impact of higher production and lower copper use resulted in a global production deficit of only 50,000 t. This followed on the heels of a large production deficit that totaled about 1.3 Mt from 2003-2004. Global world reported stocks fell by about 1.13 Mt over the same period and began 2005 at only 920,000 t or, at the prevailing rate of consumption, less than a 3-week supply (International Copper Study Group, 2006a, p. 21). Inventories held on the global commodity exchanges totaled only 124,000 t, down from 1.3 Mt at the beginning of 2003. The limited inventory coupled with the production deficit in 2005 created upward pressure on global prices and market sensitivity to announced supply disruptions. The discrepancy between the calculated production deficit and stock drawdown can readily be accounted for by the release of unreported inventories, especially those in China, the leading global consumer of copper.

While world smelter and refinery production rose by 700,000 t, world mine production rose by only 400,000 t to 15.1 Mt, with all of the increase coming as copper in concentrate. Mine capacity, however, rose by approximately 900,000 t, and capacity utilization fell to 89.4% in 2005 from 92.9% in 2004 and was at its lowest level in 10 years (International Copper Study Group, 2006b, p. 16-63). Spot treatment and refining charges at global smelters, which had fallen to almost zero at the beginning of 2004 before rising to about 34 cents per pound of copper during the fourth quarter, continued to rise during 2005 and averaged about 40 cents per pound of copper during the fourth quarter of the year (CRU International Ltd., 2006, p. 53-57). During 2004, smelters reportedly had taken advantage of a surge in concentrate availability and a rise in treatment and refining charges to rebuild diminished inventories rather than boost their output. Capacity utilization at global smelters fell to 83.1% from 84.0% in 2004 owing to a 900,000-t increase in smelter capacity (International Copper Study Group, 2006a, p. 13-14; 2006b, p. 13).

The 3-year growth in world use of refined copper stalled in 2005, and world use of copper fell to 16.63 Mt from 16.77 Mt in 2004. Asia was the only major copper consuming region of the world to experience a growth in refined copper use: Growth in apparent use in China (8%) and India (19%) overshadowed lower consumption in Japan (4%), the Republic of Korea (9%), and Taiwan (8%). In North America, only Mexico experienced a growth in use (International Copper Study Group, 2006a, p. 9-10).

Consolidation of the global copper industry continued in 2005. In North America, Canadian mining companies Noranda Inc. and Falconbridge Ltd. announced in March that they would combine the assets of the two companies under the name NorandaFalconbridge by way of a "share exchange take-over bid by Noranda." Noranda already owned 58.8% of Falconbridge. The merged entity had a production capacity of more than 550,000 t/yr of refined copper, 530,000 t/yr of zinc, and 100,000 t/yr of nickel and a fully integrated aluminum unit. The two companies already held joint interests in the Kidd Creek Mine and metallurgical facilities in Canada and the Collahuasi and Lomas Bayas Mines in Chile. The merger was completed in June, and despite the initial announcement, the merged companies carried only the Falconbridge name (Noranda Inc., 2005; Platts Metals Week, 2005b).

In a second industry consolidation, BHP Billiton (United Kingdom and Australia) announced in March that the board of

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directors of WMC Resources Ltd. (Australia) had recommended that its shareholders accept a takeover offer from BHP Billiton of $A7.85 per share for the entire issued capital of WMC Resources, thus ending a bid for control of WMC by Xstrata Plc (Switzerland) that had begun in October 2004. In June, BHP Billiton announced that it had secured more than 90% of WMC shares and that it would then proceed to compulsorily acquire the balance. The principal asset in the acquisition was WMC's Olympic Mine Dam, the world's fourth largest identified copper resource, one of the world's ten largest gold deposits, and a major producer of uranium ore. BHP Billiton already controlled a majority interest in Escondida (Chile), the world's leading copper mine and largest identified resource (BHP Billiton, 2005a, b).

World Review

Mine production.—In 2005, world mine capacity continued its strong upward growth, increasing by 900,000 t (5.6%). There was significant capacity growth in Indonesia (260,000 t), Zambia (150,000 t), Chile (130,000 t), China (65,000 t), Brazil (60,000 t), Australia (50,000 t), and Iran (30,000 t). In Indonesia, effective capacity had been reduced by about 280,000 t in 2004 from its engineered capacity when landslides limited access to high-grade ore in the Grasberg Mine (International Copper Study Group, 2006b, p. 12-63).

Australia.—Several new mines began operation during the year. At the Whim Creek Mine (Straits Resources Ltd., Perth, Australia), electrowon cathode production began in June, and by mid-October, the mine reportedly was operating at its full capacity of 17,000 t/yr of cathode. Production of concentrate at the Tritton underground mine (also owned by Straits Resources) began in April, and the company shipped more than 78,000 t of concentrate in 2005. Annual capacity was projected to be 25,000 t/yr of copper in concentrate over an 11-year life (Straits Resources Ltd., 2006, p. 10-12). The Telfer Mine (Newcrest Mining Ltd., Melbourne, Victoria, Australia), which had operated as an open pit gold operation until 2000, was recommissioned and began producing gold-copper concentrate from a new processing train in November 2004 and started a second processing train in February 2005. At capacity, the mine was projected to produce 24,000 t/yr of copper in concentrate. The company reported combined reserves accessible by open pit and underground mining that containing 590,000 t of copper and 530 t of gold (Newcrest Mining Ltd., 2006§).

Brazil.—The Sossego Mine experienced its first year of full production, having produced it first concentrate in June 2004. Production in 2005 rose to 107,000 t of copper in concentrate from 73,000 t in 2004. The open pit operation, which was expected to produce 140,000 t/yr of copper at full capacity, had a projected life of about 14 years and was the first of five copper projects owned by Companhia Vale do Rio Doce (CVRD) in Brazil to be developed. In October, CVRD's board of directors approved investing in CVRD's Project 118, slated to produce 45,000 t/yr of electrowon cathode beginning in 2007 (Companhia Vale do Rio Doce, 2006, p. 41-42).

Chile.—Expansions at the Escondida Mine and Corporación Nacional del Cobré de Chile's (Codelco) (Santiago, Chile) Norte Division were partially balanced by reduced capacity from falling ore grades at the Los Pelambres and Los Bronces Mines. Total production from Codelco's mines declined nominally to 1.83 Mt from 1.84 Mt in 2004. Despite a capacity increase at Codelco Norte, production fell to 965,000 t from 983,000 t in 2004 owing to failure of a semiautogenous grinding mill. Production at Codelco's El Teniente, Andina, and Salvador, divisions rose nominally to 437,000 t, 248,000 t, and 77,500 t, respectively. Basic engineering was completed on Codelco's proposed Gaby project, which was expected to produce 150,000 t/yr of electrowon cathode beginning in 2008 (Corporación Nacional del Cobré de Chile, 2006, p. 26-42). Though production at the Escondida Mine rose to 1.27 Mt from 1.21 Mt in 2004 following commissioning of the Norte crusher and ore handling system, production fell short of expectations owing to technical problems (BHP Billiton, 2006, p. 6).

Zambia.—First Quantum Minerals Ltd. (Vancouver) reported producing 69,600 t of copper (41,500 t in electrowon copper and 28,100 t in concentrate) from its newly restarted Kansanshi Mine [formerly owned by Zambian Consolidated Copper Mines (ZCCM) and subsequently by Cyprus Amax Minerals Company]. First Quantum estimated the combined cash cost of production at $0.63 per pound of copper. Production fell short of expectations owing to a shortage of mining equipment. Full capacity was projected at about 150,000 t of copper per year, equally split between concentrate and electrowon copper (First Quantum Minerals Ltd., 2006, p. 3). Capacity also increased at the Chambishi Mine, which was reopened in 2003 by China's Non-Ferrous Metal Mining Co., which had purchased an 85% share in the operations from ZCCM.

Smelter Production.—World smelter capacity rose by approximately 1 million metric tons per year (Mt/yr) to a record-high 20.3 Mt/yr. With the exception of small incremental increases, China, India, and Thailand accounted for most of the expansion (International Copper Study Group, 2006b, p. 64-89).

China.—Capacity rose by more than 400,000 t/yr to about 2.2 Mt/yr. The Jinchuan smelter doubled its capacity to 250,000 t/yr of anode; the Daye Non-Ferrous Metal Co. smelter reached full capacity of 200,000 t/yr; the Huludao smelter installed Ausmelt technology to double capacity to about 120,000 t/yr; and by yearend, Jinchuan Non-Ferrous Metal Co. had completed the smelter expansion that increased capacity to 350,000 t/yr of anode from 130,000 t/yr over a 2-year period (International Copper Study Group, 2006b, p. 65-66).

India.—The Birla Copper Unit of Hindalco Industries Ltd. (Worli, Mumbai, India) commissioned a new Ausmelt copper smelting and converting plant in November 2004 that will allow capacity to double to about 500,000 t/yr in 2006 from 250,000 t/yr (Ausmelt Ltd., 2004). In 2005, Sterlite Industries Ltd. (Aurangabad, India) commissioned a new ISASMELT smelter at Tuticorin in southern India that doubled its capacity to 300,000 t/yr of copper from 150,000 t/yr. The new furnace replaced an ISASMELT furnace commissioned in 1996 (Xstrata Plc., 2006§).

Thailand.—The Rayong copper smelter, about 170 km from Bangkok, was completed in mid-2004. The smelter employs a rotary smelting reactor and Chilean Teniente converting technology. Though the smelter experienced technical problems at startup, the new smelter and associated refinery were designed

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to have the capacity to produce 165,000 t/yr of cathode, 150,000 t/yr from concentrate and 15,000 t/yr from scrap (Aker Kvaerner ASA, 2005§).

Refinery Production.—Total world refinery capacity also rose by approximately 1 Mt/yr (5%) to more than 20 Mt/yr. New electrowinning capacity accounted for about 160,000 t/yr of the expansion. For the most part, increased capacity was matched to expansions in smelting capacity. Exceptions included expansion of Southern Copper Corp.'s (Phoenix, AZ) Ilo refinery in Peru to 350,000 t/yr from 290,000 t/yr prior to expansion of smelting capacity and commissioning in India of the Jhagadia Ltd. 50,000-t/yr electrolytic refinery, which was designed to process high-grade scrap (International Copper Study Group, 2006b, p. 80-103).

Outlook

Heading into 2006, the refined copper production deficit that had persisted during the preceding 3 years resulted in tight supplies, limited stock availability, and concerns over supply adequacy. Copper availability remained extremely tight during the first 9 months of 2006, with estimated production only slightly exceeding consumption. Reported global inventories declined by 20,000 t from those at yearend 2005 (International Copper Study Group, 2006a, p. 9). Global mine production in 2006 was expected to fall short of expectations owing to production problems in Chile, Indonesia, and the United States, as well as labor disruptions in Chile and Mexico. Copper prices continued their upward trend, and in May 2006, the COMEX spot price reached a record-high price of $4.08 per pound, nearly twice the previous record-high price of $2.28 set in December 2005, before settling back to an average of $3.54 per pound during the fourth quarter. Higher metal prices also led to increased investment interest in metal markets, including copper, and speculation as to the long-term effects high prices could have on substitution and demand for copper. Record-high profits led to competition for and continued consolidation of international copper mining companies.

In the United States, mine production in 2006 was expected to rise to the highest level since 2001, following a post-strike return to full production at Asarco's mines; startup of new mines in Montana, Nevada, and Utah; and restart of concentrate production at the Morenci Mine. Consumption of refined copper was expected to decline further owing to the compound effects of a turndown in the housing market, substitution for copper tubing occasioned by the high copper prices, and greater import penetration by foreign copper wire rod. U.S. mine and refinery production were expected to increase further in 2007 as new operations started up or reached capacity.

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TABLE 1
SALIENT COPPER STATISTICS[1]

(Metric tons, copper, unless otherwise specified)

		2001	2002	2003	2004	2005
United States:						
Production:						
Mine:						
Ore concentrated, gross weight	thousand metric tons	148,000	104,000	114,000	139,000	154,000
Average yield of copper[2]	percent	0.48	0.52	0.46	0.38	0.34
Recoverable copper:						
Arizona		879,000	767,000	741,000	723,000	690,000
Michigan, Montana, Utah		W	W	W	W	W
New Mexico		141,000	112,000	87,800	122,000	131,000
Other States		318,000	263,000	287,000	312,000	319,000
Total		1,340,000	1,140,000	1,120,000	1,160,000	1,140,000
Total value	millions	$2,270	$1,910	$2,100	$3,420	$4,360
Smelter:						
Primary and secondary, gross weight		919,000	683,000	539,000	542,000	523,000
Byproduct sulfuric acid, sulfur content	thousand metric tons	813	695	590	600	575
Refinery:						
Primary materials:						
Electrolytic from domestic ores		808,000	725,000	532,000	531,000	524,000
Electrolytic from foreign materials		192,000	116,000	130,000	140,000	130,000
Electrowon		628,000	601,000 r	591,000	584,000	554,000
Total		1,630,000	1,440,000	1,250,000	1,260,000	1,210,000

See footnotes at end of table.

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TABLE 1—Continued
SALIENT COPPER STATISTICS[1]

(Metric tons, copper, unless otherwise specified)

		2001	2002	2003	2004	2005
United States—Continued:						
Production—Continued:						
Refinery—Continued:						
Secondary materials (scrap), electrolytic and fire refined		172,000	69,900	53,300	50,800	47,200
Total refinery		1,800,000	1,510,000	1,310,000	1,310,000	1,260,000
Secondary copper:						
Recovered from new scrap		833,000	840,000	737,000	774,000	769,000
Recovered from old scrap		317,000	190,000	207,000	191,000	182,000
Total		1,150,000	1,030,000	944,000	965,000	951,000
Copper sulfate, gross weight		55,200	49,200	32,100	25,100	25,600
Exports:						
Refined		22,500	26,600	93,300	118,000	39,500
Unmanufactured[3]		556,000	506,000	703,000	789,000	815,000
Imports:						
Refined		991,000	927,000	882,000	807,000	1,000,000
Unmanufactured[3]		1,400,000	1,230,000	1,140,000	1,060,000	1,230,000
Stocks, December 31:						
Blister and in-process material		98,000	44,400	56,800	51,400	44,300
Refined copper:						
Refineries		28,600	11,700	12,100	10,400	8,190
Wire-rod mills		37,600	23,000	29,700	20,300	20,400
Brass mills		25,500	28,700	20,200	21,500	24,500
Other industry		4,860	4,800	4,240	3,230	5,750
New York Commodity Exchange (COMEX)		244,000	362,000	255,000	43,700	6,180
London Metal Exchange (LME), U.S. warehouses		617,000	601,000	335,000	35,000	800
Total		957,000	1,030,000	656,000	134,000	65,900
Consumption:						
Refined copper, reported		2,620,000	2,370,000	2,290,000	2,410,000	2,270,000
Apparent consumption, primary refined and old scrap[4]		2,510,000	2,610,000	2,430,000	2,550,000	2,400,000
Price:						
Producer, weighted average	cents per pound	76.85	75.80	85.25	133.94	173.49
COMEX, first position	do.	72.57	71.67	81.05	128.97	168.23
LME, Grade A cash	do.	71.57	70.72	80.68	129.96	166.84
World, production:						
Mine	thousand metric tons	13,700 r	13,700 r	13,700 r	14,700 r	15,100 e
Smelter, gross weight	do.	12,700 r	12,500 r	12,700 r	12,800 r	13,500 e
Refinery	do.	15,700 r	15,500 r	15,300 r	15,900 r	16,600

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data; included in "Other States."

[1]Data are rounded to no more than three significant digits, except prices; may not add to totals shown.

[2]Yield calculations are for concentrated ore only.

[3]Includes copper content of alloy scrap.

[4]In 2001, 2002, 2003, 2004, and 2005, apparent consumption is calculated using general imports of 1,200,000 metric tons (t) , 1,060,000 t, 687,000 t, 704,000 t, and 977,000 t, respectively.

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TABLE 2

LEADING COPPER-PRODUCING MINES IN THE UNITED STATES IN 2005, IN ORDER OF OUTPUT[1]

Rank	Mine	County and State	Operator	Source of copper	Capacity (thousand metric tons)
1	Morenci	Greenlee, AZ	Phelps Dodge Corp.	Copper ore, leached	390
2	Bingham Canyon	Salt Lake, UT	Kennecott Utah Copper Corp.	Copper-molybdenum ore, concentrated	300
3	Ray	Pinal, AZ	ASARCO Incorporated	Copper ore, concentrated and leached	170
4	Bagdad	Yavapai, AZ	Phelps Dodge Corp.	Copper-molybdenum ore, concentrated and leached	100
5	Chino	Grant, NM	do.	do.	125
6	Sierrita	Pima, AZ	do.	do.	100
7	Tyrone	Grant, NM	do.	Copper ore, leached	80
8	Continental Pit	Silver Bow, MT	Montana Resources	Copper-molybdenum ore, concentrated	45
9	Mission Complex	Pima, AZ	ASARCO Incorporated	Copper ore, concentrated	70
10	Silver Bell	do.	do.	Copper ore, leached	22
11	Robinson	White Pine, NV	Quadra Mining Ltd.	Copper-molybdenum ore, concentrated	60
12	Miami	Gila, AZ	Phelps Dodge Corp.	Copper ore, leached	50
13	Pinto Valley	do.	BHP Copper Co.	do.	5
14	Miami	do.	do.	do.	5

[1]The mines on this list accounted for more than 99% of U.S. mine production in 2005.

TABLE 3

MINE PRODUCTION OF COPPER-BEARING ORES AND RECOVERABLE COPPER CONTENT OF ORES PRODUCED IN THE UNITED STATES, BY SOURCE AND TREATMENT PROCESS[1]

(Metric tons)

	2004		2005	
Source and treatment process	Gross weight[2]	Recoverable copper	Gross weight[2]	Recoverable copper
Mined copper ore:				
Concentrated	139,000,000	533,000	154,000,000	529,000
Leached	NA	584,000	NA	554,000
Total	NA	1,120,000	NA	1,080,000
Copper precipitates shipped, leached from tailings, dumps, and in-place material	1,270	2,360	1,490	1,990
Other copper-bearing ores[3]	4,780,000	37,200	5,170,000	55,000
Grand total	XX	1,160,000	XX	1,140,000

NA Not available. XX Not applicable.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]In 2005, 14,518 kilograms of gold and 207 metric tons of silver were recovered from concentrated ore. The average value of gold and silver per metric ton of ore concentrated was $1.66.

[3]Includes gold ore, lead ore, silver ore, silver-copper ore, zinc ore, and ore shipped directly to smelter.

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TABLE 4

CONSUMPTION OF COPPER AND BRASS MATERIALS IN THE UNITED STATES, BY ITEM[1]

(Metric tons, gross weight)

Item	Brass mills	Wire-rod mills	Foundries, chemical plants, miscellaneous users	Smelters, refiners, ingot makers	Total
2004:					
Copper scrap	876,000 [r, 2]	W	80,700	183,000	1,140,000
Refined copper[3]	573,000	1,780,000	57,400	4,560	2,410,000
Hardeners and master alloys	10,000	--	2,040	--	12,100
Brass ingots	1,470	--	95,200	--	96,600
Slab zinc	68,300	--	(4)	(4)	95,500
2005:					
Copper scrap	870,000	W	81,700	192,000	1,140,000
Refined copper[3]	528,000	1,680,000	60,700	4,540	2,270,000
Hardeners and master alloys	10,000	--	2,330	--	12,400
Brass ingots	--	--	89,900	--	89,900
Slab zinc	59,700	--	(4)	(4)	82,500

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Brass mills." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes item indicated by symbol W.

[3]Detailed information on consumption of refined copper can be found in table 5.

[4]Withheld to avoid disclosing company proprietary data; included in "Total."

TABLE 5

CONSUMPTION OF REFINED COPPER SHAPES IN THE UNITED STATES, BY CLASS OF CONSUMER[1]

(Metric tons, copper)

Class of consumer	Cathodes	Ingots and ingot bars	Cakes and slabs	Wirebar, billets, other	Total
2004:					
Wire-rod mills	1,770,000	--	--	8,860	1,780,000
Brass mills	389,000	15,100	57,000	112,000	573,000
Chemical plants	--	--	--	1,200	1,200
Ingot makers	W	W	W	4,560 [2]	4,560
Foundries	3,470	6,230	--	11,300	21,000
Miscellaneous[3]	W	W	W	35,200 [2]	35,200
Total	2,160,000	21,400	57,000	173,000	2,410,000
2005:					
Wire-rod mills	1,680,000	--	--	2,590	1,680,000
Brass mills	361,000	23,300	35,300	108,000	528,000
Chemical plants	--	--	--	1,200	1,200
Ingot makers	W	W	W	4,540 [2]	4,540
Foundries	3,780	5,490	--	10,900	20,200
Miscellaneous[3]	W	W	W	39,300 [2]	39,300
Total	2,040,000	28,800	35,300	167,000	2,270,000

W Withheld to avoid disclosing company proprietary data; included with "Wirebar, billets, other." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes items indicated by symbol W.

[3]Includes consumers of copper powder and copper shot, iron and steel plants, and other manufacturers.

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TABLE 6
COPPER RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES,
BY KIND OF SCRAP AND FORM OF RECOVERY[1]

(Metric tons, copper)

	2004	2005
Kind of scrap:		
New scrap:		
Copper-base	735,000	730,000
Aluminum-base	38,800	39,300
Nickel-base	18	18
Total	774,000	769,000
Old scrap:		
Copper-base	169,000	168,000
Aluminum-base	22,100	14,200
Nickel-base	279	214
Zinc-base	29	33
Total	191,000	182,000
Grand total	965,000	951,000
Form of recovery:		
As unalloyed copper	51,400	48,100
In brass and bronze	840,000	837,000
In alloy iron and steel	1,020	985
In aluminum alloys	60,400	53,400
In other alloys	28	32
In chemical compounds	12,300	12,300
Total	965,000	951,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 7
COPPER RECOVERED AS REFINED COPPER AND IN ALLOYS AND OTHER FORMS
FROM COPPER-BASE SCRAP PROCESSED IN THE UNITED STATES, BY TYPE OF OPERATION[1]

(Metric tons, copper)

	From new scrap		From old scrap		Total	
Type of operation	2004	2005	2004	2005	2004	2005
Ingot makers	25,700	24,100	63,800	70,100	89,500	94,200
Refineries[2]	16,000	16,000	34,700	31,200	50,800	47,200
Brass and wire-rod mills	669,000	667,000	36,300	29,800	705,000	697,000
Foundries and manufacturers	19,400	17,500	30,800	33,700	50,200	51,200
Chemical plants	5,040	5,040	3,130	3,130	8,160	8,160
Total	735,000	730,000	169,000	168,000	904,000	898,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Electrolytically refined based on source of material at smelter level.

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TABLE 8
PRODUCTION OF SECONDARY COPPER AND COPPER-ALLOY PRODUCTS
IN THE UNITED STATES, BY ITEM PRODUCED FROM SCRAP[1]

(Metric tons, gross weight)

Item produced from scrap	2004	2005
Unalloyed copper products:		
Refined copper	50,800	47,200
Copper powder	48	314
Copper castings	574	547
Total	51,400	48,100
Alloyed copper products:		
Brass and bronze ingots:		
Tin bronzes	10,200	10,100
Leaded red brass and semired brass	68,400	68,700
High leaded tin bronze	10,400	10,500
Yellow brass	5,890	5,910
Manganese bronze	8,270	8,240
Aluminum bronze	6,010	5,980
Nickel silver	2,140	1,990
Silicon bronze and brass	5,900	6,010
Copper-base hardeners and master alloys	5,500	5,810
Miscellaneous	4,940	4,930
Total	128,000	128,000
Brass mill and wire-rod mill products	865,000	859,000
Brass and bronze castings	44,100 r	45,300
Brass powder	71	69
Copper in chemical products	12,300	12,300
Grand total	1,100,000	1,090,000

rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 9
COMPOSITION OF SECONDARY COPPER-ALLOY PRODUCTION IN THE UNITED STATES[1]

(Metric tons)

	Copper	Tin	Lead	Zinc	Nickel	Aluminum	Total
Brass and bronze ingot production:[2]							
2004	107,000	3,830 r	5,760 r	10,500 r	225 r	14	128,000
2005	109,000	3,750	5,510	9,150	184	12	128,000
Secondary metal content of brass mill products:							
2004	706,000	475	6,160	150,000	W	W	865,000
2005	698,000	1,750	3,590	154,000	W	W	859,000
Secondary metal content of brass and bronze castings:							
2004	39,200 r	1,520	1,130	2,030	182	62	44,100 r
2005	40,600	1,450	1,100	1,940	116	60	45,300

rRevised. W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes approximately 96% from scrap and 4% from other than scrap in 2004 and 2005.

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TABLE 10
CONSUMPTION AND YEAREND STOCKS OF COPPER-BASE SCRAP[1]

(Metric tons, gross weight)

Scrap type and processor	2004 Consumption	2004 Stocks	2005 Consumption	2005 Stocks
Unalloyed scrap:				
No. 1 wire and heavy:				
Smelters, refiners, and ingot makers	58,600	980 r	68,700	5,890
Brass and wire-rod mills	394,000	(2)	382,000	(2)
Foundries and miscellaneous manufacturers	27,200	(2)	28,000	(2)
No. 2 mixed heavy and light:				
Smelters, refiners, and ingot makers	28,800	2,090 r	34,900	1,220
Brass and wire-rod mills	6,250	(2)	5,260	(2)
Foundries and miscellaneous manufacturers	3,570	(2)	5,160	(2)
Total unalloyed scrap:				
Smelters, refiners, and ingot makers	87,400	3,070 r	104,000	7,120
Brass and wire-rod mills	401,000	28,800	387,000	33,800
Foundries and miscellaneous manufacturers	30,700	2,550	33,200	2,220
Alloyed scrap:				
Red brass:[3]				
Smelters, refiners, and ingot makers	26,300	1,360 r	22,900	1,340
Brass mills	14,200	(2)	14,330	(2)
Foundries and miscellaneous manufacturers	9,820	(2)	7,900	(2)
Leaded yellow brass:				
Smelters, refiners, and ingot makers	8,140	735 r	8,010	746
Brass mills	314,000	(2)	183,000	(2)
Foundries and miscellaneous manufacturers	1,150	(2)	981	(2)
Yellow and low brass, all plants	42,600	948 r	174,000	901
Cartridge cases and brass, all plants	86,700	(2)	94,600	(2)
Auto radiators:				
Smelters, refiners, and ingot makers	25,000	1,048 r	24,300	1,020
Foundries and miscellaneous manufacturers	4,300	(2)	5,030	(2)
Bronzes:				
Smelters, refiners, and ingot makers	11,100	750 r	10,300	625
Brass mills and miscellaneous manufacturers	18,400	(2)	17,900	(2)
Nickel-copper alloys, all plants	20,900	224 r	18,700	211
Low grade and residues, smelters, refiners, miscellaneous manufacturers	35,300	619	35,000	630
Other alloy scrap:[4]				
Smelters, refiners, and ingot makers	1,130	382 r	1,180	372
Brass mills and miscellaneous manufacturers	6,000	(2)	5,398	(2)
Total alloyed scrap:				
Smelters, refiners, and ingot makers	95,500	6,070 r	88,800	5,850
Brass mills	480,000	25,000	487,000	24,300
Foundries and miscellaneous manufacturers	50,000	2,150 r	48,500	2,160
Total scrap:				
Smelters, refiners, and ingot makers	183,000	9,140 r	193,000	13,000
Brass and wire-rod mills	881,000	53,800	874,000	58,100
Foundries and miscellaneous manufacturers	80,700	4,700 r	81,700	4,380

rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Individual breakdown is not available; included in "Total unalloyed scrap," "Total alloyed scrap," and "Total scrap."

[3]Includes cocks and faucets, commercial bronze, composition turnings, gilding metal, railroad car boxes, and silicon bronze.

[4]Includes aluminum bronze, beryllium copper, and refinery brass.

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TABLE 11
CONSUMPTION OF PURCHASED COPPER-BASE SCRAP[1, 2]

(Metric tons, gross weight)

Type of operation	From new scrap		From old scrap		Total	
	2004	2005	2004	2005	2004	2005
Ingot makers	40,200	48,100	91,700	96,600	132,000	145,000
Smelters and refineries	16,200	16,200	34,900	31,700	51,100	47,800
Brass and wire-rod mills	843,000	842,000	37,700	31,600	880,000	874,000
Foundries and miscellaneous manufacturers	42,600	40,100	38,200	41,600	80,700	81,700
Total	942,000	947,000	202,000	201,000	1,140,000	1,150,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Consumption at brass and wire-rod mills assumed equal to receipts.

TABLE 12
FOUNDRIES AND MISCELLANEOUS MANUFACTURERS CONSUMPTION OF BRASS INGOT, REFINED COPPER, AND COPPER SCRAP IN THE UNITED STATES[1]

(Metric tons, gross weight)

Ingot type or material consumed	2004	2005
Brass ingot:		
Tin bronzes	22,800	16,400
Leaded red brass and semired brass	55,300	54,400
Yellow, leaded, low brass[2]	6,440	7,850
Manganese bronze	3,930 r	3,870
Nickel silver[3]	2,270 r	2,410
Aluminum bronze	3,580 r	3,970
Hardeners and master alloys[4]	2,040	2,330
Lead free alloys[5]	864	974
Total brass ingot	97,200	92,200
Refined copper	57,400	60,700
Copper scrap	80,700	81,700

rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes brass and silicon bronze.
[3]Includes brass, copper nickel, and nickel bronze.
[4]Includes special alloys.
[5]Includes copper-bismuth and copper-bismuth-selenium alloys.

TABLE 13
AVERAGE PRICES FOR COPPER SCRAP AND ALLOY-INGOT, BY TYPE

(Cents per pound)

			Dealers' buying (New York)	
Year	Brass mills No. 1 scrap	Refiners No. 2 scrap	No. 2 scrap	Red brass turnings and borings
2004	126.41	107.62	86.86	55.14
2005	153.46	137.28	95.92	61.10

Source: American Metal Market.

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TABLE 14

U.S. EXPORTS OF UNMANUFACTURED COPPER, BY COUNTRY[1]

Country	Ore and concentrate		Matte, ash and precipitates		Refined		Unalloyed copper scrap		Blister and anodes		Total	
	Quantity (metric tons, Cu content)	Value (thousands)	Quantity (metric tons, Cu content)	Value (thousands)	Quantity (metric tons, Cu content)	Value (thousands)	Quantity (metric tons, Cu content)	Value (thousands)	Quantity (metric tons, Cu content)	Value (thousands)	Quantity (metric tons, Cu content)	Value (thousands)
2004	24,200	$48,172	22,137	$27,154	118,289	$232,811	325,118	$430,226	46,404	$120,534	536,148	$858,897
2005:												
Belgium	41	73	37	10	49	73	644	1,250	724	1,410	1,500	2,820
Canada	18,300	32,400	30,900	35,600	2,070	6,020	27,900	33,300	20,500	35,400	99,700	143,000
China	75,700	111,000	9,650	10,600	19,000	47,300	265,000	440,000	343	1,270	369,000	610,000
Germany	--	--	93	131	182	277	10,600	16,400	779	2,980	11,600	19,800
Hong Kong	2	3	1	7	7	13	9,200	7,650	3,190	12,900	12,400	20,600
India	149	177	1	33	6,650	5,720	4,460	4,930	58	205	11,300	11,100
Japan	28,700	49,200	70	126	5	8	6,710	21,900	2,230	4,830	37,800	76,100
Korea, Republic of	1	4	32	46	132	285	27,200	69,900	464	1,910	27,900	72,200
Malaysia	10	19	--	--	--	--	33	22	117	367	160	408
Mexico	6,380	13,200	682	849	9,860	33,900	1,010	3,070	2,660	8,680	20,600	59,700
Peru	--	--	1	11	28	42	--	--	--	--	29	53
Singapore	19	43	20	96	13	75	1	7	491	1,960	544	2,180
Spain	1,730	7,670	--	--	--	--	146	472	203	837	2,080	8,980
Taiwan	15	25	14	27	180	280	11,600	32,500	1,680	6,820	13,500	39,700
Thailand	5,390	10,700	(2)	5	--	--	874	2,400	125	520	6,390	13,600
United Kingdom	67	84	46	65	158	328	276	1,040	223	1,010	770	2,530
Other	136	234	302	691	1,190	2,600	1,080	2,470	7,730	16,200	10,400	22,200
Total	137,000	224,000	41,800	48,300	39,500	97,000	366,000	637,000	41,600	97,300	626,000	1,100,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 15

U.S. EXPORTS OF COPPER SEMIMANUFACTURES, BY COUNTRY[1]

Country	Pipes and tubing		Plates, sheets, foil, bars		Bare wire, including wire rod[2]		Wire and cable, stranded		Copper sulfate	
	Quantity (metric tons, copper)	Value (thousands)	Quantity (metric tons, copper)	Value (thousands)	Quantity (metric tons, copper)	Value (thousands)	Quantity (metric tons, copper)	Value (thousands)	Quantity (metric tons, copper)	Value (thousands)
2004	24,800	$102,000	29,600	$120,000	148,000	$464,000	32,400	$175,000	1,440	$1,710
2005:										
Australia	26	103	25	109	3	58	91	2,540	--	--
Brazil	38	207	36	910	4	85	69	1,160	--	--
Canada	7,140	36,400	14,500	70,300	16,200	67,700	5,870	28,400	1,530	2,040
China	71	267	615	3,530	3,110	6,110	2,960	7,540	353	525
Denmark	--	--	9	58	16	147	38	495	--	--
France	19	66	65	805	179	2,020	192	2,220	--	--
Germany	50	133	136	1,310	206	3,570	154	3,520	5	4
Hong Kong	43	195	1,060	5,890	64	779	245	3,100	--	--
Italy	--	--	6	142	4	105	85	391	--	--
Japan	8	76	501	3,370	34	265	430	3,780	38	74
Korea, Republic of	10	53	1,670	4,990	374	1,040	270	3,100	20	33
Malaysia	258	1,690	263	1,810	83	452	10	289	9	8
Mexico	20,100	88,100	7,710	28,400	132,000	517,000	18,700	98,200	79	78
Netherlands	20	159	201	1,130	30	408	104	1,390	105	187
Saudi Arabia	362	1,820	-[3]	6	5	65	72	423	--	--
Singapore	40	415	158	1,230	14	245	328	3,470	25	20
Sweden	--	--	20	257	22	355	17	644	--	--
Taiwan	20	106	121	1,530	19	214	383	1,880	11	9
Thailand	-[3]	13	352	2,090	68	486	26	972	3	3
United Kingdom	56	312	91	1,200	153	1,060	82	2,460	--	--
Other	954	4,510	920	7,110	1,600	6,200	8,680	46,100	1,050	1,540
Total	29,200	135,000	28,500	136,000	154,000	608,000	38,800	212,000	3,220	4,520

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Total revised exports of wire rod in 2004 were 128,563 metric tons (t) valued at $389 million, and in 2005, wire rod exports were 137,515 t valued at $530 million.

[3]Less than ½ unit.

Source: U.S. Census Bureau, adjusted by the U.S. Geological Survey for misclassified wire rod shipments to Mexico.

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TABLE 16

U.S. IMPORTS FOR CONSUMPTION OF UNMANUFACTURED COPPER, BY COUNTRY[1]

Country	Ore and concentrate		Matte, ash and precipitates		Blister and anode		Refined		Unalloyed scrap		Total	
	Quantity (metric tons, Cu content)	Value[2] (thousands)	Quantity (metric tons, Cu content)	Value[2] (thousands)	Quantity (metric tons, Cu content)	Value[2] (thousands)	Quantity (metric tons, Cu content)	Value[2] (thousands)	Quantity (metric tons, Cu content)	Value[2] (thousands)	Quantity (metric tons, Cu content)	Value[2] (thousands)
2004	22,900	$25,000	1,680	$3,850	151,000	$423,000	807,000	$2,170,000	23,400	$37,100	1,010,000	$2,660,000
2005:												
Belgium	--	--	--	--	--	--	8,160	32,800	--	--	8,160	32,800
Brazil	--	--	--	--	10	158	30,500	112,000	--	--	30,500	112,000
Canada	2	2	138	656	86,500	257,000	296,000	881,000	9,080	22,500	391,000	1,160,000
Chile	--	--	--	--	41,700	152,000	429,000	1,620,000	842	3,730	471,000	1,780,000
Costa Rica	--	--	--	--	--	--	--	--	2,020	1,780	2,020	1,780
Dominican Republic	--	--	--	--	--	--	--	--	210	197	210	197
Finland	--	--	--	--	65	335	2,910	12,300	--	--	2,980	12,700
Germany	--	--	--	--	12	42	24,900	95,200	85	20	25,000	95,300
Honduras	--	--	--	--	--	--	--	--	1,910	3,320	1,910	3,320
Japan	--	--	--	--	(3)	5	5,340	23,700	70	350	5,410	24,100
Mexico	221	473	37	34	3,870	13,200	28,900	94,000	13,300	36,100	46,400	144,000
Peru	--	--	--	--	--	--	154,000	565,000	54	223	154,000	565,000
Taiwan	--	--	1,180	3,410	--	--	--	--	2	16	1,180	3,430
United Kingdom	--	--	35	118	(3)	24	(3)	10	258	1,340	293	1,490
Other	--	--	253	676	16	47	24,700	98,600	2,220	3,440	27,200	103,000
Total	223	476	1,640	4,890	132,000	423,000	1,000,000	3,540,000	30,100	73,000	1,170,000	4,040,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Cost, insurance, freight value at U.S. port.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 17

U.S. IMPORTS FOR CONSUMPTION OF COPPER SEMIMANUFACTURES, BY COUNTRY[1]

	Pipes and tubing		Plates, sheets, foil, bars		Bare wire, including wire rod[2]		Wire and cable, stranded		Copper sulfate	
Country	Quantity (metric tons, copper)	Value[3] (thousands)	Quantity (metric tons, copper)	Value[3] (thousands)	Quantity (metric tons, copper)	Value[3] (thousands)	Quantity (metric tons, copper)	Value[3] (thousands)	Quantity (metric tons, copper)	Value[3] (thousands)
2004	957	$5,090	83,600	$335,000	242,000	$842,000	7,920	$34,100	56,100	$55,100
2005:										
Australia	--	--	248	879	--	--	1	21	--	--
Belgium	1	20	122	644	--	--	(4)	10	287	349
Brazil	10	57	636	3,230	36,800	139,000	--	--	--	--
Canada	167	939	6,080	31,400	156,000	597,000	377	2,410	8,290	9,230
Chile	7	37	6,130	27,000	--	--	44	163	541	625
China	124	632	1,700	8,970	201	849	4,400	7,810	6,460	6,930
Finland	9	160	3,500	20,900	496	2,400	42	253	--	--
France	2	223	3,470	15,900	362	4,290	27	420	37	43
Germany	104	539	24,800	112,000	897	5,530	433	3,060	3	27
Israel	--	--	5	100	5	43	2,210	13,900	--	--
Italy	(4)	12	1,940	8,540	2	38	1	13	--	--
Japan	4	49	2,920	17,000	227	2,020	5	57	33	180
Luxembourg	--	--	928	8,120	--	--	--	--	--	--
Mexico	45	326	1,810	8,620	77,800	286,000	2,780	10,000	34,600	40,900
Norway	--	--	--	--	--	--	--	--	--	--
Peru	--	--	4,720	19,900	743	3,140	190	802	1,050	1,230
Russia	--	--	(4)	7	102,000	392,000	--	--	196	258
Sweden	(4)	7	9,500	48,400	67	357	(4)	2	--	--
Taiwan	2	38	26	255	128	610	24	437	3,950	3,760
Turkey	--	--	--	--	8,120	40,000	652	3,340	--	--
United Kingdom	14	86	401	1,760	556	2,620	14	155	(4)	4
Other	15	183	2,780	13,500	301	2,580	365	2,740	442	450
Total	505	3,310	71,800	347,000	385,000	1,480,000	11,600	45,600	55,900	64,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Total revised imports of wire rod in 2004 were 227,791 metric tons (t) valued at $709 million, and in 2005, wire rod imports were 365,901 t valued at $1.38 million.

[3]Cost, insurance, freight value at U.S. port.

[4]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 18
U.S. EXPORTS OF COPPER SCRAP, BY COUNTRY[1]

	Unalloyed copper scrap				Copper-alloy scrap			
	2004		2005		2004		2005	
Country	Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)
Belgium	3,850	$4,490	644	$1,250	8,200	$8,930	6,890	$10,500
Canada	33,300	43,500	27,900	33,300	15,000	27,000	13,900	28,900
China	222,000	257,000	265,000	440,000	239,000	220,000	182,000	236,000
Germany	8,830	15,300	10,600	16,400	13,800	20,600	9,990	15,900
Hong Kong	3,910	9,480	9,200	7,650	11,000	9,800	12,800	13,300
India	4,160	5,900	4,460	4,930	45,100	45,000	15,800	27,200
Japan	7,930	15,800	6,710	21,900	9,660	25,900	7,950	20,400
Korea, Republic of	22,400	40,900	27,200	69,900	16,300	40,000	10,200	20,500
Mexico	4,560	12,300	1,010	3,070	1,570	4,720	1,570	5,140
Taiwan	11,300	21,000	11,600	32,500	13,700	26,300	10,600	20,100
Other	3,060	4,210	2,410	6,410	15,800	23,600	19,700	21,100
Total	325,000	430,000	366,000	637,000	389,000	451,000	291,000	419,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 19
U.S. IMPORTS FOR CONSUMPTION OF COPPER SCRAP, BY COUNTRY[1]

	Unalloyed copper scrap		Copper-alloy scrap		
	Quantity		Quantity		
Country	(metric tons, gross weight)	Value[2] (thousands)	Gross weight (metric tons)	Cu content[e, 3] (metric tons)	Value[2] (thousands)
2004	23,400	$37,100	78,300	56,400	$150,000
2005:					
Canada	9,080	22,500	47,700	34,400	123,000
Costa Rica	2,020	1,780	495	356	1,130
El Salvador	358	517	73	52	119
Germany	85	20	76	55	497
Guatemala	79	123	1,500	1,080	4,290
Honduras	1,910	3,320	651	468	1,330
Mexico	13,300	36,100	24,800	17,800	43,700
Taiwan	2	16	348	251	1,050
United Kingdom	258	1,340	925	666	2,740
Venezuela	--	--	193	139	170
Other	2,960	7,290	6,920	4,980	24,200
Total	30,100	73,000	83,700	60,200	203,000

[e]Estimated. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Cost, insurance, freight value at U.S. port.

[3]Content is estimated by the U.S. Geological Survey to be 72% of gross weight.

Source: U.S. Census Bureau.

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TABLE 20

COPPER: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005[e]
Argentina	191,667	204,027 [r]	199,020	177,143	188,000
Armenia	16,460	16,641	18,000 [e]	17,700 [e]	16,400
Australia:					
Concentrates	769,000	787,000	763,000	795,800	876,000 [3]
Leaching, electrowon	102,000	96,000 [e]	67,000	58,300	51,000 [3]
Total	871,000	883,000 [e]	830,000	854,100	927,000 [3]
Bolivia	18 [e]	3	182	596 [r]	714 [3]
Botswana[e]	19,200 [r]	21,600 [r]	27,400 [r]	22,500 [r, 3]	26,100
Brazil	32,734	32,711	26,275	103,153 [r]	131,000 [p]
Bulgaria	88,000	92,800	91,700	93,000	97,000
Burma, leaching, electrowon	25,800	27,500	27,870 [r]	31,756	34,478 [3]
Canada, concentrates	633,531	603,498	557,082	566,491 [r]	566,500 [p]
Chile:[4]					
Concentrates	3,200,800	2,979,000	3,251,100	3,776,200	3,735,900 [p, 3]
Leaching, electrowon	1,538,200	1,602,000	1,653,100	1,636,300	1,584,600 [p, 3]
Total	4,739,000	4,581,000	4,904,200	5,412,500	5,320,500 [p, 3]
China:[e]					
Concentrates	587,000	568,000	610,000	742,000 [r]	740,000
Leaching, electrowon	18,000	25,000	10,000	10,000	15,000
Total	605,000	593,000	620,000	752,000 [r]	755,000
Colombia	2,192	1,853	1,578 [r]	1,701 [r]	1,700
Congo (Kinshasa):[e, 5]					
Concentrates	37,800 [r]	27,500 [r]	30,300 [r]	31,800 [r]	49,500 [3]
Leaching, electrowon	--	6,500 [r]	29,500 [r]	41,500 [r]	56,500
Total	37,800 [r]	34,000 [r]	59,800 [r]	73,300 [r]	106,000
Cuba[e]	1,000	1,000	--	--	--
Cyprus, leaching, electrowon	5,176	3,695	2,552	1,240	--
Ecuador[e]	100	100	100	100	--
Finland	13,715	14,400	14,900	15,500	15,000 [3]
Georgia[e]	8,000	10,000	12,000	12,000	12,000
India	32,400	31,500	28,500	29,500 [r]	26,900 [3]
Indonesia[5]	1,081,040	1,171,726 [r]	1,005,831 [r]	840,318	1,065,000 [3]
Iran:[e]					
Concentrates	121,000	121,000	130,000	150,000 [r]	185,000
Leaching, electrowon	12,000	12,000	12,000	12,000	12,000
Total	133,000	133,000	142,000	162,000 [r]	197,000
Japan	744	-- [r]	-- [r]	-- [r]	--
Kazakhstan[e]	470,100 [3]	490,000	485,000	461,000 [3]	402,000
Korea, North[e]	12,000	12,000	12,000	12,000	12,000
Laos	--	--	--	--	30,500
Macedonia[e]	9,000	5,600	700 [r]	-- [r]	22,000
Mexico:					
Concentrates	310,623	260,574	284,653	333,540	350,000
Leaching, electrowon	60,500	69,300 [r]	71,000	72,000	75,000
Total	371,123	329,874 [r]	355,653	405,540	425,000
Mongolia	133,503	131,705	131,600	132,000	126,547 [3]
Morocco	5,400 [r]	5,000	4,900	4,400 [r]	4,400
Namibia	12,393 [r]	18,012	16,175 [r]	11,174 [r]	10,900
Pakistan	--	--	3,200	15,000	17,700 [3]
Papua New Guinea	218,000 [e]	211,311	190,200	173,400	193,000 [3]
Peru:					
Concentrates	590,896	686,748	660,025	868,574	844,368 [3]
Leaching, electrowon	131,409 [r]	156,467 [r]	171,198	167,000	165,530 [3]
Total	722,305 [r]	843,215 [r]	831,223	1,035,574	1,009,898 [3]

See footnotes at end of table.

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TABLE 20—Continued

COPPER: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005[e]
Philippines	20,322	18,364	20,400	15,984 [r]	16,323 [3]
Poland	474,000	502,800	495,000	531,000	523,000
Portugal	82,900	77,000	78,000	96,000	89,500
Romania[6]	19,185	18,962	23,389 [r]	18,767 [r]	15,000
Russia[e]	600,000	695,000	675,000	675,000	700,000
Saudi Arabia[e]	800	800	800	500	700
Serbia and Montenegro[e]	31,000	36,900	26,400	13,000 [r]	25,000
South Africa	141,865	129,589	120,800 [r]	120,577 [r]	103,907 [p]
Spain	9,700	--	--	--	4,900 [3]
Sweden	74,269	76,200 [r]	96,000 [r]	90,600 [r]	97,800 [3]
Tanzania, in concentrates and bullion	2,645	4,191 [r]	3,715 [r]	4,133 [r]	4,200
Turkey[6]	56,864	48,253	58,000 [e]	49,000 [e]	48,000
United States:[5]					
Concentrates	714,000	601,000	525,000	576,000	586,000 [3]
Leaching, electrowon	624,000	542,000	591,000	584,000	554,000 [3]
Total	1,340,000	1,140,000	1,120,000	1,160,000	1,140,000 [3]
Uzbekistan[e]	78,000	80,000	80,000	95,000 [r]	100,000
Zambia:					
Concentrates	233,000	251,100	269,000	344,300	330,000
Leaching, electrowon	79,000	78,900	80,000	82,600	106,000
Total	312,000 [7]	330,000	349,000	426,900	436,000
Zimbabwe, concentrates	2,057	2,502	2,767	2,383	2,700
Grand total	13,700,000	13,700,000	13,700,000	14,700,000 [r]	15,100,000
Of which:					
Concentrates	11,100,000	11,000,000	11,000,000	12,000,000 [r]	12,400,000
Leaching, electrowon	2,600,000	2,620,000	2,720,000	2,700,000	2,660,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table represent copper content by analysis of concentrates produced (includes cement copper, if applicable), except where otherwise noted. Table includes data available through July 22, 2006.

[3]Reported figure.

[4]Reported by Comision Chilena del Cobre. Includes recoverable copper content of nonduplicative mine and metal products produced from domestic ores and concentrates and leach production for electrowinning.

[5]Recoverable content.

[6]Excludes copper content of pyrite.

[7]Data are for fiscal years beginning April 1 of year stated.

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TABLE 21

COPPER: WORLD SMELTER PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, gross weight)

Country	2001	2002	2003	2004	2005[e]
Armenia, primary[e]	4,000	6,700	7,500	7,500	9,800 [3]
Australia, primary	455,000	458,000 [e]	435,000	443,000	410,000 [3]
Austria, secondary	68,642	64,932	75,000	88,000	90,000
Belgium, secondary	138,200	125,900	117,500	107,000 [r]	99,200 [3]
Bolivia, primary	--	--	--	-- [r]	--
Botswana, primary[4]	19,209	21,590	25,292 [r]	21,195 [r]	26,700
Brazil, primary	212,243	189,651	173,378 [r]	208,020 [r]	210,000 [p]
Bulgaria:					
Primary	157,000 [r]	181,000 [r]	215,300 [r]	227,100 [r]	240,100 [3]
Secondary[e]	5,000	15,000	16,000	7,000	5,000
Total	162,000 [r]	196,000 [r]	231,300 [r]	234,100 [r]	245,000
Canada:					
Primary	601,359	513,934	430,116	446,221	450,000 [p]
Secondary	41,640	24,761	26,789	29,962	30,000 [p]
Total	642,999	538,695	456,905	476,183	480,000 [3]
Chile, primary	1,503,200	1,438,700	1,542,400	1,517,600	1,558,100 [p, 3]
China:[e]					
Primary	1,120,000	1,180,000	1,380,000	1,500,000 [r]	1,700,000
Secondary	190,000	310,000	350,000	440,000	540,000
Total	1,310,000	1,490,000	1,730,000	1,940,000 [r]	2,240,000
Congo (Kinshasa), primary, electrowon	25,000 [r]	10,000 [r]	8,000	20,000 [r]	10,000
Finland:					
Primary	169,300	160,900	176,400 [r]	168,600 [r]	170,000
Secondary[e]	2,000	2,000	2,000	2,000	2,000
Total	171,300	162,900	178,400 [r]	170,600 [r]	172,000
Germany:					
Primary	317,700 [r]	295,100 [r]	288,800	278,600	257,200 [3]
Secondary	240,900 [r]	283,100 [r]	306,600	262,600	251,400 [3]
Total	558,600 [r]	578,200 [r]	595,400	541,200	508,600 [3]
India:					
Primary	293,000 [e]	385,400	391,000	401,000 [r]	486,600 [3]
Secondary[e]	--	--	--	--	38,000
Total	293,000 [e]	385,400	391,000	401,000	524,600 [3]
Indonesia, undifferentiated	217,500	211,200	247,400	211,600	275,000
Iran, undifferentiated[5]	181,526 [r]	171,591 [r]	168,613 [r]	184,814 [r]	185,000
Japan:					
Primary	1,328,489	1,317,291	1,343,353	1,270,495	1,319,247 [3]
Secondary	139,764	182,069	172,724	194,927	198,516 [3]
Total	1,468,253	1,499,360	1,516,077	1,465,422	1,517,763 [3]
Kazakhstan, undifferentiated	433,600	446,200	431,930	445,200	425,000
Korea, North, primary and secondary[e]	15,000	15,000	15,000	15,000	15,000
Korea, Republic of:					
Primary	386,200 [r]	380,000 [r]	410,000 [r]	380,000 [r]	426,000
Secondary	42,300 [r]	50,000 [r]	50,000 [r]	50,000 [r]	50,000
Total	428,500	430,000	460,000	430,000	476,000 [3]
Mexico:					
Primary	305,000 [r]	243,000 [r]	238,000 [r]	274,000 [r]	290,000
Secondary[e]	5,000	5,000	5,000	5,000	5,000
Total	310,000 [r]	248,000 [r]	243,000 [r]	279,000 [r]	295,000
Namibia, primary[6, 7]	27,015	26,703	26,036	24,704 [r]	23,300
Oman, primary[e]	24,200 [3]	25,000 [r]	18,000 [r]	25,000 [r]	25,000
Peru, primary	396,400 [r]	379,600 [r]	396,100 [r]	377,800 [r]	381,600 [3]
Philippines, primary	165,000	165,800	227,900	217,300 [r]	201,300 [3]

See footnotes at end of table.

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TABLE 21—Continued
COPPER: WORLD SMELTER PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, gross weight)

Country	2001	2002	2003	2004	2005[e]
Poland:					
Primary	485,900	511,000	560,000 [r]	545,000 [r]	550,000
Secondary[e]	27,900	39,400 [r]	24,100 [r]	25,000 [r]	25,000
Total	513,800	550,400 [r]	584,100 [r]	570,000 [r]	575,000
Romania:					
Primary	9,279	8,871	4,493 [r]	61 [r]	100
Secondary[e]	2,000	2,000	500	--	--
Total	11,279	10,871	4,993 [r]	61 [r]	100
Russia:[e]					
Primary	650,000	660,000	670,000	662,000	686,000
Secondary	245,000	200,000	170,000	257,000	272,000
Total	895,000	860,000	840,000	919,000 [3]	958,000
Serbia and Montenegro:[e]					
Primary	24,000	36,000 [r]	14,000 [r]	12,000 [r]	16,300
Secondary	14,000	6,700 [r]	3,600 [r]	1,100 [r]	6,000
Total	38,000	42,700 [r]	17,600 [r]	13,100 [r]	22,300
South Africa, primary	117,237	116,996	112,025	89,300 [e]	100,000
Spain:					
Primary	255,200	281,300	276,300	210,200	278,600
Secondary[e]	24,700 [3]	16,700	14,000	14,100	5,000
Total	279,900	298,000	290,300	224,300	283,600 [3]
Sweden:[e]					
Primary	173,000	188,000	185,000	206,000 [r]	192,000
Secondary	35,000	35,000	30,000	30,000	30,000
Total	208,000	223,000	215,000	236,000 [r]	222,000
Turkey, undifferentiated[8]	33,504	32,550	30,400 [e]	11,500	9,000
United States, undifferentiated	919,000	683,000	539,000	542,000	523,000 [3]
Uzbekistan, undifferentiated[e]	90,000	75,000	75,000	105,000 [r]	115,000
Zambia, primary:					
Electrowon	50,000	60,000	50,000	60,000	50,000
Other	306,000	311,400	200,000	220,000	220,000
Total	356,000	371,400	250,000	280,000	270,000
Zimbabwe, primary[e, 6]	2,160	-- [r]	-- [r]	-- [r]	--
Grand total	12,700,000 [r]	12,500,000 [r]	12,700,000 [r]	12,800,000 [r]	13,500,000
Of which:					
Primary:					
Electrowon	75,000 [r]	70,000 [r]	58,000 [r]	80,000 [r]	60,000
Other	9,510,000 [r]	9,480,000 [r]	9,750,000 [r]	9,730,000 [r]	10,200,000
Secondary	1,220,000 [r]	1,360,000 [r]	1,360,000 [r]	1,510,000 [r]	1,650,000
Undifferentiated[9]	1,890,000 [r]	1,630,000 [r]	1,510,000 [r]	1,520,000 [r]	1,550,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]This table includes total production of smelted copper metal, including low-grade cathode produced by electrowinning methods. The smelter feed maybe derived from ore, concentrates, copper precipitate or matte (primary), and/or scrap (secondary). To the extent possible, primary and secondary output of each country is shown separately. In some cases, total smelter production is officially reported, but the distribution between primary and secondary has been estimated. Table includes data available through July 15, 2006.

[3]Reported figure.

[4]Copper content of nickel-copper matte exported to Norway for refining.

[5]Data are for year beginning March 21 of that stated. Secondary production is estimated to be about 5% of total.

[6]Includes impure cathodes produced by electrowinning in nickel processing.

[7]Includes 8,000 to 10,000 metric tons per year for 2001-05 produced from imported toll concentrates.

[8]Secondary production is estimated to be about one-third of total.

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TABLE 22

COPPER: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005
Argentina, secondary[e]	16,000	16,000	16,000	16,000	16,000
Australia, primary:					
Electrowon	102,000 [e]	96,000 [e]	67,400	58,300	50,900
Other	456,000 [e]	449,000 [e]	416,600	431,800	420,200
Total	558,000 [e]	545,000 [e]	484,000	490,100	471,100
Austria, secondary[e]	69,000	65,000	65,100 [r]	59,000 [r, 3]	52,000
Belgium:[e]					
Primary[4]	236,000	207,000	208,000	223,000	252,900 [3]
Secondary	187,000	216,000	215,000	174,000	130,000
Total	423,000	423,000	423,000	397,000	382,900 [3]
Brazil, primary	212,243	189,651	173,378 [r]	208,020 [r]	210,000 [p]
Bulgaria:[e]					
Primary	29,400 [3]	38,000	43,000	52,300	60,500
Secondary	5,000	3,000	2,000	3,000	3,000
Total	34,400	41,000	45,000	55,300	63,500
Burma, electrowon	25,800	27,500	27,900 [e]	31,800	32,000 [e]
Canada:					
Primary	524,900 [r]	469,760 [r]	428,077 [r]	495,867 [r]	483,500
Secondary	42,800	24,761	26,789	31,100	31,800
Total	567,700 [r]	494,521 [r]	454,866 [r]	526,967 [r]	515,300
Chile, primary					
Electrowon	1,538,200	1,602,000	1,653,100	1,636,300	1,584,600 [p]
Other	1,344,000	1,248,100	1,248,800	1,200,400 [r]	1,239,400 [p]
Total	2,882,200	2,850,100	2,901,900	2,836,700 [r]	2,824,000 [p]
China, primary[e]					
Primary					
Electrowon	18,000	20,000	10,000	10,000	15,000
Other	1,200,000	1,280,000	1,420,000	1,580,000 [r]	1,850,000
Secondary	300,000	350,000	430,000	620,000 [r]	750,000
Total	1,518,000 [3]	1,650,000	1,860,000	2,210,000 [r]	2,615,000 [3]
Cyprus, electrowon	5,176	3,695	2,552	1,240	--
Egypt, secondary[e]	4,000	4,000	4,000	4,000	4,000
Finland:[e]					
Primary	105,000	112,000	120,000	117,000 [r]	118,000
Secondary	15,000	15,000	15,000 [r]	16,000	16,000
Total	120,000	127,000	135,000 [r]	133,000 [r]	134,000
Germany:					
Primary	303,000 [r]	327,000 [r]	286,653 [r]	283,686 [r]	293,800
Secondary	390,773 [r]	368,791 [r]	310,925 [r]	368,956 [r]	344,400
Total	693,773 [r]	695,791 [r]	597,578 [r]	652,642 [r]	638,200
Hungary, secondary[e]	10,000	10,000	10,000	10,000	10,000
India:[e]					
Primary, electrolytic	310,000 [3]	354,000	375,000	399,000 [r]	497,000 [3]
Secondary	18,000	20,000	19,000	20,000	20,000
Total	328,000	374,000	394,000	419,000 [r]	517,000
Indonesia, primary	212,500	192,400	223,300	210,500	262,900
Iran, primary[5]					
Electrowon[e]	12,000	12,000	12,000	12,000	12,000
Other[6]	140,000 [r]	131,000 [r]	134,632	140,000 [r]	163,100
Total	152,000 [r]	143,000 [r]	146,632	152,000 [r]	175,100
Italy, secondary	35,500	32,400	26,700 [e]	34,000 [r]	32,200

See footnotes at end of table.

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TABLE 22—Continued
COPPER: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005
Japan:					
Primary	1,287,165	1,211,111	1,251,728	1,188,491	1,227,528
Secondary	138,526	189,968	178,637	191,653	167,756
Total	1,425,691	1,401,079	1,430,365	1,380,144	1,395,284
Kazakhstan, primary	425,700	453,000	432,901	445,200	418,833
Korea, North, primary[e]	15,000 [r]	15,000 [r]	15,000 [r]	15,000 [r]	15,000
Korea, Republic of, undifferentiated	473,252 [r]	499,116 [r]	509,970 [r]	495,952 [r]	526,566
Laos, electrowon	--	--	--	--	30,500
Mexico, primary:					
Electrowon	60,500 [r]	69,300 [r]	71,000 [r]	72,000 [e]	75,000 [e]
Other	332,500 [r]	318,700 [r]	249,000 [r]	321,000 [r]	325,000 [e]
Secondary	15,000	35,000	35,000	35,000	35,000
Total[e]	408,000 [r]	423,000 [r]	355,000 [r]	428,000 [r]	435,000
Mongolia, electrowon	1,476	1,500	1,341	2,376 [r]	2,475
Norway, primary[6]	26,700	30,500 [e]	35,900	35,600	38,500
Oman, primary[e]	24,000	24,000	17,000	24,000 [r]	24,000
Peru, primary:					
Electrowon	131,409 [r]	156,467 [r]	171,198	167,000	165,530
Other	342,502 [r]	346,282 [r]	345,848	338,308	344,862
Total	473,911 [r]	502,749 [r]	517,046	505,308	510,392
Philippines, primary	164,530	144,315	171,200 [3]	175,000	172,000
Poland:					
Primary	498,451	508,674	513,600 [r]	531,100 [r]	540,300
Secondary	30,286	19,146	16,000 [r]	21,000 [r]	20,000
Total	528,737	527,820	529,600 [r]	552,100 [r]	560,300
Romania:					
Primary	18,500	11,453	16,739	24,383	30,000
Secondary[e]	4,000	2,000	2,000	2,000	2,000
Total	22,500	13,453	18,739	26,383	32,000
Russia:					
Primary	650,000	670,000 [e]	670,000 [e]	662,000	664,000
Secondary	244,500	200,000 [e]	170,000 [e]	257,000	269,000
Total	894,500	870,000 [e]	840,000 [e]	919,000	933,000
Serbia and Montenegro:					
Primary	32,365	35,897	14,000 [r]	12,000 [r]	23,000
Secondary[e]	17,000 [r]	17,000 [r]	8,000 [r]	7,000 [r]	7,000
Total	49,365 [r]	52,897 [r]	22,000 [r]	19,000 [r]	30,000
South Africa, primary[6]	132,000 [r]	119,970 [r]	111,400 [r]	91,495 [r]	97,000
Spain:					
Primary	235,100	272,000 [e]	259,000 [e]	193,200	242,700
Secondary[e]	55,600 [3]	37,000	35,000	35,000	26,300 [3]
Total	290,700	309,000 [e]	294,000 [e]	228,200	269,000
Sweden:[e]					
Primary	179,000 [3]	199,000	189,000	210,000	200,000
Secondary	25,000	25,000	25,000	25,000	22,000
Total	204,000 [3]	224,000	214,000	235,000	222,000
Taiwan, secondary[e]	4,000	4,000	4,000	4,000	4,000
Thailand, primary	--	--	--	27,200 [r]	26,100
Turkey:[e]					
Primary	54,400	39,000	40,000	45,000	90,000
Secondary	4,000	2,000	5,000	5,000	5,000
Total	58,400	41,000	45,000	50,000	95,000
Ukraine, secondary	--	10	20	20	20

See footnotes at end of table.

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TABLE 22—Continued
COPPER: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005
United States:					
Primary:					
Electrowon	628,000	601,000 r	591,000	584,000	554,000
Other	1,000,000	841,000	662,000	671,000	654,000
Secondary	172,000	69,900	53,300	50,800	47,200
Total	1,800,000	1,510,000	1,310,000	1,310,000	1,260,000
Uzbekistan:[e]					
Primary	80,000	75,000	75,000	105,000 r	115,000
Secondary	10,000	--	--	--	--
Total	90,000	75,000	75,000	105,000 r	115,000
Zambia, primary:					
Electrowon[7]	79,000	83,700	109,000	124,000 r	150,000 e
Other	217,500	253,100	240,800	286,000 r	244,000 e
Total	296,500	336,800	349,800	410,000 r	394,000 e
Zimbabwe, primary	5,300 e	2,502	2,767	2,383	2,400 e
Grand total	15,700,000 r	15,500,000 r	15,300,000 r	15,900,000 r	16,600,000 e
Of which:					
Primary:					
Electrowon	2,600,000	2,670,000	2,720,000	2,700,000	2,670,000 e
Other	11,300,000	11,100,000 r	10,900,000 r	11,200,000	11,900,000 e
Secondary	1,810,000 r	1,730,000 r	1,670,000 r	2,000,000 r	2,010,000 e

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]This table includes total production of refined copper whether produced by pyrometallurgical or electrolytic refining methods and whether derived from primary unrefined copper or from scrap. Copper cathode derived from electrowinning processing is also included. Table includes data available through July 22, 2006.

[3]Reported figure.

[4]Includes reprocessed leach cathode from Congo (Kinshasa).

[5]Data are for Iranian years beginning March 21 of that stated.

[6]May include secondary.

[7]Electrowon covers only high-grade electrowon cathodes reported as "finished production leach cathodes."

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DIAMOND, INDUSTRIAL

By Donald W. Olson

Domestic survey data and tables were prepared by Nicholas A. Muniz, statistical assistant, and the world production tables were prepared by Glenn J. Wallace, international data coordinator.

In 2005, U.S. synthetic diamond production was estimated to be 256 million carats with an estimated value of $257 million. U.S. imports of all forms of industrial diamond totaled about 286 million carats valued at almost $107 million, while exports totaled more than 92.5 million carats valued at almost $51.1 million. The estimated U.S. apparent consumption of all forms of industrial diamond was 441 million carats with an estimated value of $282 million.

Diamond is best known as a gemstone, but some of its unique properties make it ideal for many industrial and research applications as well. Current information on gem-grade diamond can be found in the U.S. Geological Survey (USGS) Minerals Yearbook, volume I, Metals and Minerals chapter on gemstones. Diamond that does not meet gem-quality standards for clarity, color, shape, or size is used as industrial-grade diamond. Production and consumption quantities and values reported are estimated to avoid disclosing company proprietary data and still provide useful data on the overall market. Trade data in this report are from the U.S. Census Bureau. All percentages in the report were computed using unrounded data.

Diamond is the hardest known material and has the highest thermal conductivity of any material at room temperature. Diamond is more than twice as hard as its nearest competitors, cubic boron nitride and silicon nitride (Ravi, 1994, p. 537). Because it is the hardest substance known, diamond has been used for centuries as an abrasive in cutting, drilling, grinding, and polishing. Industrial-grade diamond continues to be used as an abrasive for many applications. Even though it has a higher unit cost, diamond has proven to be more cost-effective in many industrial processes because it cuts faster and lasts longer than alternative abrasive materials (Boucher, 1997, p. 26.6). Diamond also has chemical, electrical, optical, and thermal characteristics that make it the best material available to industry for wear- and corrosion-resistant coatings, special lenses, heat sinks in electrical circuits, wire drawing, computing, and other advanced technologies.

Both synthetic and natural diamond have industrial uses. Synthetic industrial diamond is superior to its natural diamond counterpart because its properties can be tailored to specific applications, and it can be produced in large quantities (Boucher, 1996). It is for these reasons that synthetic diamond accounts for more than 99% of the industrial diamond used in the United States and about 87% of the industrial diamond used in the world.

Legislation and Government Programs

Congress has authorized the sale of all diamond in the National Defense Stockpile (NDS), which is managed by the Defense National Stockpile Center (DNSC). A portion of the stockpiled diamond stones was scheduled for sale in the NDS's fiscal year 2005 annual plan; however, the DNSC did not sell any industrial diamond stone during calendar year 2005. At yearend 2005, the DNSC reported an NDS remaining inventory of about 520,000 carats of industrial diamond stone with a market value of $5.2 million (Jenkins, 2005). The DNSC planned to conduct additional sales until all NDS diamond stone stocks are sold.

Production

The USGS conducts an annual survey of domestic industrial diamond producers and U.S. firms that recover diamond wastes. Although most of these companies responded to the 2005 survey, one of the two U.S. primary producers of industrial diamond and one of the four industrial diamond recycling firms withheld from the survey data that they deemed to be proprietary. To protect the proprietary data of other producers, only estimates of U.S. primary and secondary output are provided in this review.

As one of the world's leading producers of synthetic industrial diamond, the United States accounted for an estimated output of 256 million carats valued at more than $257 million in 2005. Only two U.S. companies produced synthetic industrial diamond during the year—Diamond Innovations, Inc., Worthington, OH, and Mypodiamond, Inc., Smithfield, PA.

In 2005, nine companies also manufactured polycrystalline diamond (PCD) from synthetic diamond grit and powder. These companies were Dennis Tool Co., Houston, TX; Diamond Innovations; Novatek Inc., Provo, UT; Phoenix Crystal Corp., Ann Arbor, MI; Precorp Inc., Provo; SII Megadiamond Industries Inc., Provo; Tempo Technology Corp., Somerset, NJ; U.S. Synthetics Corp., Orem, UT; and Western Diamond Products, Salt Lake City, UT.

It is estimated that about 4.59 million carats of used industrial diamond was recycled in the United States during 2005. Recycling firms recovered most of this material from used diamond drill bits, diamond tools, and other diamond-containing wastes. Additional diamond was recovered during the year from residues generated in the manufacture of PCD; most of this material was recovered from within the production operations of the PCD-producing companies.

The recovery and sale of industrial diamond was the principal business of four U.S. companies in 2005—Industrial Diamond Laboratory Inc., Bronx, NY; Industrial Diamond Powders Co., Pittsburgh, PA; International Diamond Services Inc., Houston; and National Research Co., Fraser, MI. In addition to these companies, other domestic firms may have recovered industrial diamond in smaller secondary operations.

There have been no commercially operated diamond mines in the United States since 2002. Diamond was produced at the

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Kelsey Lake diamond mine, located close to the Colorado-Wyoming State line near Fort Collins, CO, for several years until April 2002. The Kelsey Lake property includes nine known kimberlite pipes, three of which have been tested and have shown that diamonds are present. The remaining six pipes have yet to be fully explored and tested for their diamond potential. Of the diamonds recovered, 35% to 50% was industrial grade. The identified resources are at least 17 million metric tons (Mt) grading an average of 4 carats per 100 metric tons (Taylor Hard Money Advisers, 2000§[1]).

Studies by the Wyoming Geological Survey have shown that Wyoming has the potential for a $1 billion diamond mining business. Wyoming has many of the same geologic conditions as Canada, and there is evidence of hundreds of kimberlite pipes in the State. Twenty diamondiferous kimberlite pipes and one diamondiferous mafic breccia pipe have been identified in southern Wyoming. Two of the largest kimberlite fields, State Line and Iron Mountain, and the largest lamproite field in the United States, Leucite Hills, are in Wyoming. Several diamond mining firms have been interested in the southern Wyoming and northern Colorado area, but the only diamond mine developed in the area thus far is the Kelsey Lake Mine (Associated Press, 2002§).

The success of Canadian diamond mines has stimulated interest in exploring for commercially feasible diamond deposits in the United States outside of Wyoming and Colorado. Australian and Canadian companies are now conducting diamond exploration in Alaska and Minnesota. Alaska has some similar geologic terrain to the Northwest Territories; in addition, certain varieties of garnet and other diamond indicator minerals as well as 17 microscopic diamonds have been found near Anchorage, AK. Two Canadian companies have invested $1 million in an exploratory drilling program. Geologists from the University of Minnesota teamed with an Australian mining company and were conducting a soil sampling program in Minnesota for mineral exploration, including diamond. The samples were being analyzed by Australia's WMC Resources Ltd. The scientists believe that there is good chance of success owing to similarities between the geology in Minnesota and Canada (Diamond Registry Bulletin, 2005).

In another exploration venture, Delta Mining and Exploration Corp. found a diamond-bearing kimberlite in an 80-acre (32.4-hectare) site known as the Homestead property near Lewistown, MT. Preliminary tests have shown the presence of microscopic diamonds. The company was planning a $700,000 soil sampling program as further exploration. Diamonds have been found in the stream beds and glacial valleys of Montana for years (Associated Press, 2004§).

Consumption

The United States remained the world's leading market for industrial diamond in 2005. Based on production estimates, trade data, and adjustments for Government stockpile sales, apparent U.S. consumption of industrial diamond during the year increased by almost 7% to an estimated 442 million carats valued at $282 million. This apparent consumption was the combination of 441 million carats of diamond bort, grit, dust and powder valued at $277 million and 1.22 million carats of diamond stone valued at $4.78 million.

The major consuming industries of industrial diamond in the United States during 2005 were construction, machinery manufacturing, mining services (exploration drilling for minerals, oil, and gas), stone cutting/polishing, and transportation systems (infrastructure and vehicles). Within these sectors, stone cutting and highway building/repair together made up the largest demand for industrial diamond. The manufacture of each automobile made in the United States consumes about 1.5 carats of industrial diamond. Research and high-technology uses included close-tolerance machining of ceramic parts for the aerospace industry, heat sinks in electronic circuits, lenses for laser radiation equipment, and polishing silicon wafers and disks drives in the computer industry (Bailey and Bex, 1995).

Diamond tools have numerous industrial functions. Diamond drilling bits and reaming shells are used principally for gas, mineral, and oil exploration. Other applications of diamond bits and reaming shells include foundation testing, masonry drilling, and inspecting concrete. The primary uses of point diamond tools are for dressing and truing grinding wheels and for boring, cutting, finishing, and machining applications. Beveling glass for automobile windows is another application. Cutting dimension stone and cutting/grooving concrete in highway reconditioning are the main uses of diamond saws; other applications include cutting composites and forming refractory shapes for furnace linings. Very fine diamond saws are used to slice brittle metals and crystals into thin wafers for electronic and electrical devices. Diamond wire dies are essential for high-speed drawing of fine wire, especially from hard, high-strength metals and alloys. The primary uses of diamond grinding wheels include edging plate glass, grinding dies, grinding parts for optical instruments, and sharpening and shaping carbide machine tool tips.

Two types of natural diamond are used by industry—diamond stone (generally larger than 60 mesh/250 micrometers) and diamond bort (smaller, fragmented material). Diamond stone is used mainly in drilling bits and reaming shells used by mining companies; it also is incorporated in single- or multiple-point diamond tools, diamond saws, diamond wheels, and diamond wire dies. Diamond bort is used for drilling bits and as a loose grain abrasive for polishing. Other tools that incorporate natural diamond include bearings, engraving points, glass cutters, and surgical instruments.

Synthetic diamond grit and powder are used in diamond grinding wheels, saws, impregnated bits and tools, and as a loose abrasive for polishing. Diamond grinding wheels can be as much as 1 meter in diameter.

Loose powders made with synthetic diamond for polishing are used primarily to finish cutting tools, gemstones, jewel bearings, optical surfaces, silicon wafers, and wire-drawing dies for computer chips. Hundreds of other products made from ceramics, glass, metals, and plastics also are finished with diamond powders.

The use of polycrystalline diamond shapes (PDSs) and polycrystalline diamond compacts (PDCs) continues to increase for many of the applications cited above, including some of those that employ natural diamond. The use of PDSs, PDCs, and matrix-set synthetic diamond grit for drilling bits and reaming

[1]References that include a section mark (§) are found in the Internet References Cited section.

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shells has increased in recent years. PDSs and PDCs are used in the manufacture of single- and multiple-point tools, and PDCs are used in a majority of the diamond wire-drawing dies.

Prices

Natural and synthetic industrial diamonds differ significantly in price (Boucher, 1997, p. 26.6). Natural industrial diamond normally has a more limited range of values. Its price varies from about $0.33 per carat for bort size material to about $7 to $10 per carat for most stones, with some larger stones selling for up to $200 per carat.

Synthetic industrial diamond has a much larger price range than natural diamond. Prices of synthetic diamond vary according to particle strength, size, shape, crystallinity, and the absence or presence of metal coatings. In general, synthetic diamond prices for grinding and polishing range from as low as $0.33 to $1.67 per carat. Strong and blocky material for sawing and drilling sells for $1.50 to $3.50 per carat. Large synthetic crystals with excellent structure for specific applications sell for many hundreds of dollars per carat (Law-West, 2002, p. 23.8).

Foreign Trade

The United States continued to lead the world in industrial diamond trade in 2005; imports were received from 47 countries, exports were sent to 58 countries, and reexports were sent to 65 countries (tables 1-4). Although the United States has been a major producer of synthetic diamond for decades, growing domestic markets have become more reliant on foreign sources of industrial diamond in recent years. U.S. markets for natural industrial diamond always have been dependent on imports and secondary recovery operations because there has been no domestic production of natural diamond.

During 2005, U.S. imports of industrial-quality diamond stones (natural and synthetic) increased by 19% from those of 2004 to about 2.12 million carats valued at more than $29.5 million (table 1). Imports of diamond dust, grit, and powder (natural and synthetic) increased by 18% from those of 2004 to 284 million carats valued at almost $77.3 million (table 2).

Reexports may account for a significant portion of total exports/reexports; therefore, exports and reexports are listed separately in tables 3 and 4 so that U.S. trade and consumption can be calculated more accurately. During 2005, U.S. exports of industrial diamond stones decreased from those of 2004 to 424 carats valued at $18,000, and U.S. reexports of industrial diamond stone decreased by 21% from those of 2004 to 1.43 million carats valued at $26.1 million (table 3). U.S. exports of industrial diamond dust, grit, and powder (natural and synthetic) increased by 8% from those of 2004 to 92.5 million carats valued at $51.1 million, and reexports of industrial diamond dust, grit, and powder (natural and synthetic) decreased by 4% from those of 2004 to 11.6 million carats valued at $8.14 million (table 4).

World Industry Structure

In 2005, industrial diamond was produced in 28 countries (tables 5-6). Total industrial diamond output worldwide was estimated by the USGS to be in excess of 644 million carats valued between $644 million and $1 billion. Natural industrial diamond production worldwide was estimated to be more than 81.0 million carats, a slight decrease compared with that of 2004. Congo (Kinshasa) was the leading producing country, followed by Australia and Russia, in descending order of quantity. These three countries produced more than 74% of the world's natural industrial diamond (table 5). Synthetic industrial diamond production worldwide was estimated to be more than 563 million carats, a slight increase compared with the previous year. The United States was the leading producing country, followed by Russia, Ireland, and South Africa, in descending order of quantity. These four countries produced about 81% of the world's synthetic industrial diamond (table 6).

In addition to the countries listed in table 6, Germany and the Republic of Korea produced synthetic diamond, but specific data on their output could not be confirmed. China may have produced more than the output listed in the table (Wilson Born, National Research Co., oral commun., 2004).

In 2005, 80% of the total global natural and synthetic industrial diamond output was produced in Ireland, Japan, Russia, South Africa, and the United States. Synthetic diamond accounted for more than 87% of global diamond production and consumption.

World Review

Canada.—The Ekati Diamond Mine, Canada's first operating commercial diamond mine, completed its seventh full year of production. In 2005, Ekati produced 3.23 million carats of diamond from 4.44 Mt of ore (BHP Billiton Ltd., 2006b). BHP Billiton Ltd. has an 80% controlling ownership in Ekati, which is in the Northwest Territories in Canada. Ekati has estimated reserves of 60.3 Mt of ore in kimberlite pipes that contain 54.3 million carats of diamond, and BHP Billiton projected the mine life to be 25 years. The Ekati mine is now producing from the Koala, Panda, and Misery kimberlite pipes. BHP Billiton is using underground mining techniques to recover diamonds from deeper portions of the Panda kimberlite pipe (BHP Billiton Ltd., 2004). Underground mining of the deeper portions of the Koala kimberlite pipe has been approved and is expected to begin in December 2007 (BHP Billiton Ltd., 2006a). Both the Koala and Panda kimberlite pipes were first open pit mined (Diamond Registry Bulletin, 2002). Approximately one-third of the Ekati diamond production is industrial-grade material (Darren Dyck, senior project geologist, BHP Diamonds, Inc., oral commun., May 27, 2001).

The Diavik Diamond Mine, also in the Northwest Territories, completed its third full year of production. In 2005, Diavik produced 8.3 million carats of diamond from its A154 North ore body and the adjacent A154 South pipe. Both pipes are located within the same pit (Diavik Diamond Mines Inc., 2006). Diavik has estimated the mine's remaining proven and probable reserves to be 29.8 Mt of ore in kimberlite pipes, containing 95.6 million carats of diamond, and projected the mine life to be 16 to 22 years (Diavik Diamond Mines Inc., 2005). The mine is an unincorporated joint venture between Diavik Diamond Mines Inc. (60%) and Aber Diamond Mines Ltd. (40%). The

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mine is expected to produce a total of about 107 million carats of diamond at a rate of 8 million carats per year worth about $63 per carat over the entire mine life, which began production in December 2002 (Diavik Diamond Mines Inc., 2000, p. 10-12).

Diamond exploration is continuing in Canada, with several other commercial diamond projects and additional discoveries located in Alberta, British Columbia, the Northwest Territories, the Nunavut Territory, Ontario, and Quebec. Canada produced about 7% of the world's combined natural gemstone and industrial diamond production in 2005.

Current Research and Technology

Apollo Diamond, Inc., near Boston, MA, has developed and patented a method for growing extremely pure, gem-quality diamond with flawless crystal structure by chemical vapor deposition (CVD). The CVD technique transforms carbon into plasma, which then is precipitated onto a substrate as diamond. CVD has been used for more than a decade to cover large surfaces with microscopic diamond crystals, but until this process, no one had discovered the combination of temperature, gas composition, and pressure that resulted in the growth of a single diamond crystal. CVD diamond precipitates as nearly 100% pure, almost flawless diamond, and therefore may not be distinguishable from natural diamond by some tests (Davis, 2003).

Apollo Diamond produced stones that range from 1 to 2 carats in 2005 and expected to expand to larger stones in the future (Maney, 2005§). The company planned to start selling diamonds in the jewelry market at costs 10% to 30% below those of comparable natural diamonds (Hastings, 2005). Apollo Diamond planned to open the Apollo Diamond Web store to the general public in 2006 (Apollo Diamond, Inc., 2005§).

CVD diamond's highest value besides its use as gemstones is as a material for high-tech uses. CVD diamond could be used to make extremely powerful lasers; to create cell phones that fit into a watch and storage devices for MP3 players that could store 10,000 movies, not just 10,000 songs; to create frictionless medical replacement joints; or as coatings for cars that would not scratch or wear out. The greatest potential use for CVD diamond is in computer technology (Maney, 2005§). For diamond to be a practical material for use as a semiconductor, it must be affordably grown in large wafers. After Apollo's process and technology are fully developed, CVD diamond could possibly be grown for prices as low as $5 per carat. CVD growth is limited only by the size of the seed placed in the diamond growing chamber. Starting with a square, wafer-like fragment, the Apollo Diamond process grows the diamond into a prismatic shape, with the top slightly wider than the base. For the past 7 years, Apollo Diamond has been growing increasingly larger seeds by chopping off the top layer of growth and using that as the starting point for the next batch. At the moment, the company is producing 10-millimeter wafers but predicts it will reach about 10 times that in the near future (Davis, 2003). Scientists have said that diamond computer chips are more durable because they can work at temperatures up to 1,000° C, while silicon computer chips stop working at about 150° C. This means that diamond computer chips could work at a much higher frequency or faster speed and could be placed in a high-temperature environment (Diamond Registry Bulletin, 2003§).

In early 2004, scientists at the Carnegie Institution of Washington's Geophysical Laboratory published a study showing that researchers grew diamond crystals by a special CVD process at very high growth rates. They were able to grow gem-sized crystals in a day—a growth rate 100 times faster than other methods used before. This is a new way of producing diamond crystals for such new applications as diamond-base electronic devices and next generation cutting tools (Willis, 2004). By early 2005, the Carnegie Institution's Geophysical Laboratory and the University of Alabama had jointly developed and patented the CVD process and apparatus to produce 10-carat, ½-inch thick single diamond crystals at very rapid growth rates (100 micrometers per hour). This faster CVD method uses microwave plasma technology and allows multiple crystals to be grown simultaneously. This size is about five times that of commercially available lab-created diamonds produced by high pressures and high temperatures (HPHT) methods and other CVD techniques. Dr. Russell Hemley, a researcher at the Carnegie Institution stated, "High-quality crystals over 3 carats are very difficult to produce using the conventional approach. Several groups have begun to grow diamond single crystals by CVD, but large, colorless, and flawless ones remain a challenge. Our fabrication of 10-carat, half-inch, CVD diamonds is a major breakthrough" (Willis, 2004; Carnegie Institution of Washington, 2005; Science Blog, 2005§).

Both Apollo Diamond and the Carnegie Institution have noted that their diamonds produced by the CVD method are harder than natural diamonds and diamonds produced by HPHT methods.

Outlook

The United States will most likely continue to be the world's leading market for industrial diamond well into the next decade. The United States also is expected to remain a significant producer and exporter of industrial diamond. The strength of U.S. demand will depend on the vitality of the Nation's industrial base and on how well the diamond life cycle cost-effectiveness compares with competing materials that initially are less expensive. Diamond offers many advantages for precision machining and longer tool life. In fact, even the use of wear-resistant diamond coatings to increase the life of materials that compete with diamond is a rapidly growing application. Increased tool life not only leads to lower costs per unit of output but also means fewer tool changes and longer production runs (Advanced Materials & Processes, 1998). In view of the many advantages that come from increased tool life and reports that diamond film surfaces can increase durability by a factor of 50, much wider use of diamond as an engineering material is expected.

The most dramatic increase in domestic use of industrial diamond is likely to be in the construction sector as the Nation builds and repairs the U.S. highway system in its implementation of the Safe, Accountable, Flexible, and Efficient Transportation Equity Act of 2005 (Public Law 109-59), which was passed by the U.S. House of Representatives on March

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10, 2005, and by the U.S. Senate on May 17, 2005. This Act authorized appropriations for fiscal years 2005 through 2009 for Federal-aid highway programs out of the Highway Trust Fund (U.S. House of Representatives, 2005§). Demand for saw-grade diamond alone is expected to increase in 2006 if goals mandated by the Act for the repair and replacement of roads, bridges, and other components in the transportation infrastructure of the country are fulfilled.

PCD for abrasive tools and wear parts will continue to replace competing materials in many industrial applications by providing closer tolerances as well as extending tool life. For example, PDCs and PDSs will continue to displace natural diamond stone and tungsten carbide products used in the drilling and tooling industries (Wilson Born, National Research Co., written commun., 1998).

Truing and dressing applications will remain a major domestic end use for natural industrial diamond stone. Stones for these applications have not yet been manufactured economically. No shortage of the stone is anticipated, however, because new mines and more producers selling in the rough diamond market will maintain ample supplies. More competition introduced by the additional sources also may temper price increases.

World demand for industrial diamond will continue to increase during the next few years. Constant dollar prices of synthetic diamond products, including CVD diamond films, will decline as production technologies become more cost effective and as competition increases from low-cost producers in China and Russia.

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TABLE 1

U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL DIAMOND STONES, BY COUNTRY[1]

(Thousand carats and thousand dollars)

	Natural industrial diamond stones[2]				Miners' diamond, natural and synthetic[3]			
	2004		2005		2004		2005	
Country	Quantity	Value[4]	Quantity	Value[4]	Quantity	Value[4]	Quantity	Value[4]
Australia	22	159	69	456	7	61	5	108
Belgium	105	590	49	321	94	541	32	198
Botswana	175	3,450	794	14,100	(5)	23	(5)	5
Brazil	--	--	8	130	(5)	10	5	16
Canada	6	162	(5)	11	(5)	5	1	42
China	--	--	--	--	(5)	8	--	--
Congo (Kinshasa)	20	375	87	403	2	12	4	169
Ghana	113	652	97	721	17	158	68	144
Guyana	--	--	(5)	23	--	--	(5)	13
India	3	65	81	37	--	--	33	82
Ireland	41	55	--	--	572	263	--	--
Japan	--	--	--	--	16	75	--	--
Mexico	3	19	--	--	(5)	22	--	--
Namibia	146	658	261	1,360	14	65	1	7
Russia	98	1,930	134	2,890	82	348	--	--
South Africa	198	3,460	356	7,710	2	48	4	215
Switzerland	(5)	13	5	11	(5)	36	6	16
Tanzania	1	28	2	39	--	--	--	--
United Kingdom	37	253	4	121	2	88	14	118
Other	1 r	31 r	--	--	2 r	153 r	--	--
Total	969	11,900	1,950	28,300	809	1,920	172	1,130

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes glazers' and engravers' diamond unset, Harmonized Tariff Schedule of the United States (HTS) codes 7102.21.3000 and 7102.21.4000.

[3]HTS codes 7102.21.1010 and 7102.21.1020.

[4]Customs value.

[5]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 2

U.S. IMPORTS FOR CONSUMPTION OF DIAMOND DUST, GRIT, AND POWDER, BY COUNTRY[1]

(Thousand carats and thousand dollars)

	Synthetic[2]				Natural[2]			
	2004		2005		2004		2005	
Country	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]
Australia	149	61	55	64	170	56	32	12
Austria	30	15	32	22	--	--	--	--
Belgium	13,200	3,770	8,650	3,630	473	274	962	512
Botswana	--	--	48	34	--	--	--	--
Brazil	87	87	138	117	75	75	21	25
Canada	5	3	15	11	4	6	430	14
China	85,500	8,930	119,000	14,600	259	38	506	252
Congo (Brazzaville)	25	9	--	--	--	--	--	--
Czech Republic	--	--	10	7	--	--	--	--
France	60	78	--	--	--	--	17	29
Germany	474	228	107	37	4	3	155	41
Ghana	--	--	130	57	34	26	--	--
Greece	9	12	--	--	--	--	--	--
Hong Kong	4,300	476	4,460	1,050	--	--	--	--
India	2,480	662	1,460	547	1,050	277	275	114
Ireland	65,200	29,400	83,900	38,200	1,080	457	1,570	897
Italy	2,750	1,310	1,370	660	24	29	84	74
Japan	5,990	5,120	8,470	5,530	16	22	14	24
Korea, Republic of	8,790	3,280	10,500	4,020	21	14	45	22
Macau	238	73	--	--	12	13	2	3
Mexico	--	--	229	100	10	7	115	25
Morocco	6	4	--	--	--	--	--	--
Namibia	19	34	13	46	40	171	118	322
Romania	1,150	242	1,290	196	30	8	--	--
Russia	15,400	1,550	19,300	1,780	30	83	44	20
South Africa	2	8	--	--	--	--	61	67
Spain	--	--	616	49	--	--	1	2
Sweden	5	5	--	--	--	--	--	--
Switzerland	753	958	1,070	1,210	284	281	319	425
Taiwan	171	67	277	83	--	--	27	5
Ukraine	26,100	1,720	14,600	889	--	--	24	10
United Arab Emirates	--	--	128	56	--	--	--	--
United Kingdom	3,280	981	2,760	1,180	534	246	697	294
Total	236,000	59,100	278,000	74,200	4,160	2,090	5,520	3,190

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States codes 7105.10.0020, 7105.10.0030, and 7105.10.0050 for synthetic and 7105.10.0011 and 7105.10.0015 for natural.

[3]Customs value.

Source: U.S. Census Bureau.

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TABLE 3
U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND STONES, BY COUNTRY[1]

(Thousand carats and thousand dollars)

	Industrial unworked diamonds[2]			
	2004		2005	
Country	Quantity	Value[3]	Quantity	Value[3]
Exports:				
Belgium	14	18	--	--
Canada	8	46	--	--
Hong Kong	501	375	--	--
United Kingdom	--	--	(4)	18
Total	523	439	(4)	18
Reexports:				
Australia	4	66	(4)	28
Belgium	805	8,560	469	7,830
Brazil	4	67	4	57
Canada	69	331	149	923
China	24	135	11	86
Germany	11	113	10	385
Hong Kong	83	907	153	1,090
India	8	224	9	628
Ireland	1	8	10	32
Israel	--	--	6	1,320
Japan	410	6,230	162	7,810
Korea, Republic of	109	1,760	28	1,410
Mexico	13	146	(4)	(4)
South Africa	11	40	15	41
Switzerland	67	173	140	180
Taiwan	13	184	8	218
United Arab Emirates	6	13	152	1,690
United Kingdom	150	1,980	94	2,190
Other	27 r	274 r	20	173
Total	1,820	21,200	1,430	26,100
Grand total	2,340	21,700	1,430	26,100

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States code 7102.21.0000.

[3]Customs value.

[4]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 4

U.S. EXPORTS AND REEXPORTS OF INDUSTRIAL DIAMOND DUST, GRIT, AND POWDER, BY COUNTRY[1]

(Thousand carats and thousand dollars)

	Synthetic[2]				Natural[2]			
	2004		2005		2004		2005	
Country	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]	Quantity	Value[3]
Exports:								
Austria	196	82	144	47	42	15	--	--
Belgium	582	259	624	197	248	271	168	78
Brazil	1,730	841	3,390	1,810	--	--	--	--
Canada	2,600	2,330	3,760	3,000	84	173	229	431
France	226	60	--	--	77	131	19	36
Germany	25,400	11,200	1,320	455	319	357	102	99
Greece	246	78	720	215	--	--	--	--
Hong Kong	303	214	500	187	47	95	17	30
India	1,470	823	1,570	745	--	--	6	15
Ireland	3,490	2,000	23,500	11,600	325	261	318	417
Israel	82	34	384	134	--	--	104	33
Italy	2,230	921	4,170	1,860	50	35	37	20
Japan	18,000	8,480	21,400	9,830	966	378	493	501
Korea, Republic of	11,400	4,380	10,100	4,560	688	226	374	131
Macau	36	38	207	172	15	15	--	--
Malaysia	525	994	112	169	17	52	60	126
Mexico	391	174	459	163	45	115	294	258
Philippines	51	12	134	103	6	9	57	14
Singapore	600	729	1,460	1,450	28	25	64	128
Spain	392	92	319	87	155	42	124	29
Switzerland	1,130	1,630	3,850	3,760	2,150	3,830	825	1,180
Taiwan	3,240	1,410	1,440	1,440	58	48	36	30
Thailand	2,930	1,140	2,650	1,020	86	23	10	15
United Kingdom	1,320	429	1,460	896	186	126	283	114
Other	746 r	395 r	4,420	1,800	746 r	1,410 r	791	1,710
Total	79,400	38,800	88,000	45,700	6,330	7,640	4,410	5,400
Reexports:								
Austria	242	122	377	117	174	26	181	36
Belgium	222	138	258	213	87	95	412	299
Brazil	8	14	59	25	9	8	123	29
Canada	1,020	1,080	965	861	89	54	110	167
Germany	728	232	705	265	596	154	456	158
India	241	69	106	31	2	3	31	13
Ireland	184	193	136	169	9	14	241	67
Italy	542	132	450	114	327	84	147	38
Japan	898	375	2,330	1,310	240	49	77	10
Korea, Republic of	1,960	829	1,710	705	2,290	505	805	189
Macau	80	46	186	194	377	60	135	21
Mexico	102	34	116	72	96	39	18	16
United Arab Emirates	--	--	--	--	--	--	600	2,540
United Kingdom	204	141	157	101	337	125	252	129
Other	702 r	313 r	318	199	412 r	207 r	185	55
Total	7,140	3,720	7,870	4,370	5,050	1,420	3,770	3,770
Grand total	86,500	42,500	95,900	50,100	11,400	9,060	8,180	9,170

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States codes 7105.10.0025 for synthetic and 7105.10.0010 for natural.

[3]Customs value.

Source: U.S. Census Bureau.

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TABLE 5

NATURAL DIAMOND: WORLD PRODUCTION, BY COUNTRY AND TYPE[1, 2, 3]

(Thousand carats)

Country and type[4]	2001	2002	2003	2004	2005
Gemstones:					
Angola[e]	4,643 r	4,520	5,130 r	5,490 r	5,580
Australia	14,397 r	15,136 r	13,981 r	20,602 r	20,000 e
Botswana[e]	19,812 r, 5	21,297 r, 5	22,800	23,300	23,900
Brazil[e]	700	500 5	400 r	300 r, 5	300
Canada	3,716	4,937	10,756 r	12,618	12,300
Central African Republic[e]	340	312	250	263 r	265
China[e]	100 r	100 r	100 r	100 r	100
Congo (Kinshasa)	3,638	4,223 r	5,381 r	6,180 r	6,300 e
Côte d'Ivoire	207 e	205 r	154 r	201 r, e	201 e
Ghana	936 e	770 e	675 r	690 r	760 e
Guinea	273	368	484 6	354 r, 6	411 6
Guyana	179	248	413	455 r	357
Liberia[e]	100	48	36	18	18
Namibia	1,487	1,562	1,481	2,004 r	1,900 e
Russia[e]	17,500	17,400	20,000	21,400	23,000
Sierra Leone	102 r	162 r	233 r, e	318 r, e	318 e
South Africa	4,465 r	4,351 r	5,144 r	5,780 e	5,780 e
Tanzania[e]	216 5	204	201	258 r	175
Venezuela	14	46	11	40 e	46 e
Other[7]	54 r	42 r	44 r	74 r	110
Total	72,900 r	76,400 r	87,700 r	100,000 r	102,000
Industrial:					
Angola[e]	516	502	570 r	610 r	620
Australia	11,779 r	18,500	17,087 r	22,709 r	20,000 e
Botswana[e]	6,604 r, 5	7,100	7,600	7,800	8,000
Brazil[e]	600	600	600	600	600
Central African Republic[e]	113	104	83	88 r	88
China[e]	950	955	955	960	960
Congo (Kinshasa)	14,560	17,456	21,600	24,700 r	25,200 e
Côte d'Ivoire	102	101 r	76 r	99 r, e	99 e
Ghana[e]	234	193	225 r	230 r	253
Guinea[e]	91	123	161 6	118 r, 6	137 6
Liberia[e]	70	32	24	12	12
Russia[e]	11,700	11,600	13,000	14,200	15,000
Sierra Leone	120 r	190 r	274 r, e	374 r, e	374 e
South Africa	6,698	6,526 r	7,540 r	8,500 r, e	9,380 e
Tanzania	38	36	36	46 r	30
Venezuela	28	61	24	60 e	69 e
Other[8]	91 r	81 r	82 r	121 r	190
Total	54,300 r	64,200 r	69,900 r	81,200 r	81,000
Grand total	127,000	141,000 r	158,000 r	182,000 r	183,000

[e]Estimated. [r]Revised.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 5, 2006.

[3]In addition to the countries listed, Nigeria produces natural diamond, but information is inadequate to formulate reliable estimates of output levels.

[4]Includes near-gem and cheap-gem qualities.

[5]Reported figure.

[6]Exports.

[7]Includes Cameroon, Congo (Brazzaville), Gabon (unspecified), India, Indonesia, and Zimbabwe.

[8]Includes Congo (Brazzaville), India, Indonesia, and Zimbabwe.

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TABLE 6

SYNTHETIC DIAMOND: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2, 3]

(Thousand carats)

Country	2001	2002	2003	2004	2005
Belarus	25,000	25,000	25,000	25,000	25,000
China	17,000	17,000	17,000	17,000	17,000
Czech Republic	5	5	5	5	5
France	3,000	3,000	3,000	3,000	3,000
Ireland	60,000	60,000	60,000	60,000	60,000
Japan	33,000	34,000	34,000	34,000	34,000
Russia	80,000	80,000	80,000	80,000	80,000
South Africa	60,000	60,000	60,000	60,000	60,000
Sweden	20,000	20,000	20,000	20,000	20,000
Ukraine	8,000	8,000	8,000	8,000	8,000
United States	202,000	222,000	236,000	252,000	256,000
Total	508,000	529,000	543,000	559,000	563,000

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 5, 2006.

[3]In addition to the countries listed, Germany and the Republic of Korea also produce significant amounts of synthetic diamond, but output is not officially reported, and available information is inadequate to formulate reliable estimates of output levels.

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DIATOMITE

By Alan Founie

Domestic survey data and tables were prepared by Subina W. Pandey, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

Production of diatomite in the United States increased by 5% to 653,000 metric tons (t), and its value increased by 1% to $179 million free on board (f.o.b.) plant in 2005 compared with 620,000 t valued at $177 million f.o.b. plant in 2004 (table 1). The United States remained the world's leading producer and consumer of diatomite. Diatomite is used primarily for filtration (table 2). Major diatomite products were sold as various grades of calcined powders.

Encroachment into diatomite markets by natural and synthetic substitute materials remained minimal, and use as fillers and for biological filtration, including filtering human blood plasma, continued to grow. Other uses of diatomite included absorbents, insulation, insecticide, and as pozzolan in cement. Diatomaceous material that contains abundant clay has a growing use as a raw material in the production of portland cement, but that impure material is not considered in this report.

Domestic Data Coverage

Domestic production data for diatomite were developed by the U.S. Geological Survey (USGS) from an annual voluntary survey of U.S. diatomite-producing sites and company operations. The canvass for 2005 covered 7 diatomite-producing companies with 11 mining areas and 9 processing facilities in California, Nevada, Oregon, and Washington. Because two of the companies did not respond to the 2005 survey, sales and use data for these companies were estimated based on past production figures and man-hours worked as reported to the Mine Safety and Health Administration. Data are rounded to no more than three significant figures. All percentages in this report were computed based on unrounded data.

Description and Terminology

Diatomite is a chalk-like, soft, friable, earthy, very fine grained, siliceous sedimentary rock, usually light in color (white if pure, commonly buff to gray in situ, and rarely black). It is very finely porous, very low in density, and essentially chemically inert in most liquids and gases. Diatomaceous earth (often abbreviated as D.E.) is a common alternate name but is more appropriate for the unconsolidated or less lithified sediment. The deposits result from an accumulation in oceans or fresh waters of the amorphous hydrous silica (opal, $SiO_2 \cdot H_2O$) cell walls of dead diatoms, which are microscopic single-cell aquatic plants (algae). The diatom cells contain an internal, elaborate siliceous skeleton consisting of two valves (frustules) that vary in size from less than 1 micrometer (μm) to more than 1 millimeter in diameter but are typically 10 to 200 μm across and have a broad variety of delicate, lacy, perforated shapes varying from spheres and cylinders to discs, ladders, feathers, and needles. Additional information on the environmental and physical properties of diatoms can be found in Moyle and Dolley (2003) and Dolley and Moyle (2003).

Diatomite can form an excellent reservoir rock for hydrocarbons. The Belridge diatomite in the San Joaquin Basin in California is an example of an oil-producing diatomaceous formation (Schlumberger Limited, 2005§[1]). Diatomite is also known as kieselgur (a German name compounded from the words for flint and for an earthy sediment in water) and as tripolite after a diatomite occurrence near Tripoli, Libya. The term tripolite is used in some Government trade documents and tariff codes as the short name for a group of siliceous fossil meals and similar siliceous earths that can include diatomite (U.S. International Trade Commission, 2005§). An impure (up to 30% clay) Danish variety of diatomite is called moler.

Commercial deposits worldwide are reported to be mostly fresh water (lacustrine) deposits of Miocene to Pleistocene age. The oldest occurrences are thought to be of Cretaceous age, deposited about 138 million to 66 million years ago. It is thought that older diatomite occurrences may have altered into other forms of silica, particularly chert, owing to diagenesis, burial, and exposure. Detailed information on the geology of diatomite can be found in Wallace (2003) and Moyle and Dolley (2003).

Production

Recovery of diatomite from most deposits is by low-cost open pit mining because many occurrences are at or near the surface and the topography allows for open pit mining. Outside the United States, however, underground mining is fairly common owing to deposit form and depth as well as topography and other constraints. Explosives are not normally needed either at surface or in underground mines because of the soft, friable nature of the rock. In Iceland, dredging is used to recover diatomaceous mud from the bottom of a lake.

Diatomite usually is processed near the mine to reduce the cost of hauling the crude ore, which can contain up to 65% water. Processing typically involves a series of crushing, drying, size reduction, and calcining operations, using heated air for conveying and classifying within the plant. Fines, especially from baghouses, are used mostly for filler-grade products, and coarser particles are used for filter grades. In the latter stages of processing, calcining is normally done in rotary kilns to effect physical and chemical changes.

Production cost allocations for the United States have been reported to be 10% for mining, 60% for processing, and 30% for packing and shipping, with energy costs composing 25% to

[1]References that include a section mark (§) are found in the Internet References Cited section.

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30% of direct costs (Breese, 1994, p. 405). The proportion of the product that is calcined directly affects energy consumption.

The two leading domestic producers of diatomite underwent important changes in 2005. World Minerals, Inc. (the parent of Celite Corporation) was purchased by Imerys, USA, Inc. (a subsidiary of the French company Imerys, S.A.), and EaglePicher Incorporated filed for reorganization under Chapter 11 of the U.S. Bankruptcy Code.

In 2005, 653,000 t of diatomite was produced from 11 separate mining areas and 9 processing facilities in California, Nevada, Oregon, and Washington. Major producers were Celite Corporation (a subsidiary of Imerys, USA) (Lompoc and Quincy, WA) and EaglePicher (Lovelock and Fernley, NV, and Vale, OR). California was the leading producing State, followed closely by Nevada. The combined output of these two States accounted for about 70% of the U.S. production in 2005.

Consumption

In antiquity, diatomite was used by the Greeks as an abrasive and in making lightweight building bricks and blocks. However, diatomite only became of industrial interest in Western Europe in the mid-1800s when pulverized diatomite became the preferred absorbent and stabilizer of nitroglycerine used by Alfred Nobel to make dynamite. The site of the first U.S. production of diatomite was in Maryland in 1884. By the late 1880s, very pure, huge deposits near Lompoc became the focus of interest and has continued to dominate world markets (Dolley and Moyle, 2003). Diatomite is now used principally as a filter aid, but it is also used as an absorbent for industrial spills and for pet litter, as a filler in a variety of products from paints to dry chemicals, as an insulation material in sawn and molded shapes and loose granules, as a mild abrasive in polishes, and as a silica additive in cement and various other compounds.

Apparent domestic consumption (excluding stocks for which data were not available) of diatomite in 2005 was about 515,000 t, up by about 8% from 478,000 t in 2004. The total domestic and export quantity of filter-grade diatomite sold or used by U.S. producers was 489,000 t in 2005, up by 5% from 467,000 t in 2004, accounting for 75% of total diatomite consumption. Use of diatomite as a filler was 73,000 t in 2005, down slightly from 75,000 t in 2004, accounting for 11% of total diatomite consumption. For absorbents, 46,000 t of diatomite was consumed, about the same as in 2004, accounting for 2% of total diatomite consumption. Diatomite use for insulation rose by 6% to 12,700 t in 2005 from 12,000 t in 2004, accounting for 11% of total diatomite consumption. Consumption for other applications rose 60% in 2005 to 32,000 t, from 20,000 t in 2004, accounting for 5% of total diatomite consumption. Increased use as a pozzolan and as an ingredient in cement manufacturing constituting the majority of the other use category.

Commercial diatomite products provide fine-sized, irregular-shaped porous noncaking particles that have a large surface area and high liquid absorption capacity. They are relatively inert chemically, have a low refractive index, are mildly abrasive, have low thermal conductivity with a reasonably high fusion point, can be slightly pozzolanic, are very high in silica, and can be produced and delivered at a cost consistent with customer applications. Sawn shapes, which continue to account for a significant part of world diatomite production, have long been used as lightweight building material, especially in China, and primarily for thermal insulation (especially the high-clay-content Danish moler). Both dried natural products and calcined products are used in the aforementioned building applications. The major use of diatomite is as a filtration medium for beverages (especially beer and wine), sugar and sweetener liquors, oils and fats, petroleum and chemical processing (including reprocessing waste dry cleaning fluids), pharmaceuticals, and water (industrial process, potable, swimming pool, and waste). Another leading use is as an absorbent for industrial spills (oil and toxic liquids) and for pet litter.

Another important broad category of use is as a filler, often serving a dual purpose, such as an extender and flatting agent in paints and coatings; a bulking and anticaking agent in granular materials; and as a multieffect component in plastics (including preventing films from sticking). Other filler uses are as an extender and absorbent carrier for dry pesticides, pharmaceuticals, catalysts, and other chemicals (Crossley, 2000, p. 135). Other significant uses are as an insulation material in bulk (loose) and molded forms, other insulation products that include calcium silicate as a component, and as a silica additive in various compounds, including mortar and portland cement where it is used also for its pozzolanic properties.

Commercial diatomite products are offered in a great variety of grades. Principal grading factors are the size, shape, overall arrangement, and proportions of the various types of frustules (factors that affect filtration rate, product clarity, and absorption capacity), the content of silica, and various impurities, such as certain minerals and chemicals especially iron, a major impurity, as well as clay, sand, and organics. Additional specialized application specifications are brightness/whiteness and abrasive hardness. Reduced free-crystalline silica content, although normally low, also is required by some environmental regulations, particularly for calcined products. Calcining removes organics, increases filtration rate, oxidizes iron, increases specific gravity, increases particle hardness, and can lighten the color. Flux-calcining significantly affects the physical and chemical properties and makes a white product. Most filter grades are calcined.

Prices

The calculated weighted average unit value of diatomite sold or used by U.S. producers during 2005, using USGS survey data, was $274.02 per metric ton free on board (f.o.b.) plant, a decrease of about 4% compared with about $285.72 per ton in 2004 (table 3). The average values for filtration uses fell in 2005 to about $261.79 per ton, down by 3% from the 2004 values. The value for diatomite used for absorbents decreased by more than one-half to $30.68 per ton. The unit value for diatomite used as fillers increased by 6% to $382.27 per ton in 2005, and the value for diatomite used in insulation increased by 2% to $44.09 per ton in 2005 compared with that of 2004. The average value for specialized or other uses in 2005 fell by about 36%

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to $652.34 per ton, down from $1,020 per ton in 2004. The decreases in the unit value of use categories in 2005 probably resulted from the competition of less expensive substitutes in many uses. Diatomite used in cement manufacture commands a much lower value than some specialty uses, which most likely caused the value per ton of the other use category to drop.

Foreign Trade

Export and import data presented here, which are from the U.S. Census Bureau, are of limited accuracy owing to inconsistencies in producer reporting and because there is a lack of detail for the various materials specified in the 2005 Harmonized Tariff Schedule of the United States (HTS) issued by the U.S. International Trade Commission. Exports of diatomite from the United States in 2005 were about 142,000 t, about 1,000 t less than in 2004 (table 4). Exports accounted for about 22% of total domestic production sold or used. The trade data were issued under heading 2512 of the HTS, described as applying to natural and straight-calcined diatomite. Industry sources, however, indicated that exports also included some flux-calcined material, whish is included under code 3802.90.2000 where it is not differentiated from activated clays. Similarly, heat-insulating mixtures and sawn and molded unfired shapes of diatomite are collected under data classification code 6806.90.0090 and are not exclusively identified as diatomite. Also, fired, sawn, and molded shapes of diatomite are covered under heading 6901 that is not exclusively used for diatomite data.

According to the U.S. Census Bureau data, diatomite products were exported to 97 countries in 2005. The main export markets were Canada (21,500 t), Germany (16,300 t), Belgium (14,700 t), Japan (9,330 t), Australia (7,070 t), the United Kingdom (4,975 t), Russia (4,944 t), and Thailand (4,915 t), accounting for 59% of the total exports reported. Based on the available data, the average unit value free alongside ship of exported diatomite was $426 per ton in 2005 compared with $375 per ton in 2004, an increase of 14% (table 4). Because the data may not include all the higher value material, as discussed above, actual average unit values may be higher. Import data available for diatomite show that 4,320 t came from 12 countries in 2005. Mexico provided 2,580 t (60%), France provided 646 t (15%), and the remainder came from the Netherlands, China, Italy, Spain, Canada, Australia, Japan, Chile, Argentina, and India, in descending order of tonnage.

World Industry Structure

The estimated world production in 2005 was about 2 Mt (table 5). World reserves are estimated to be almost 1 billion metric tons (Gt), which is more than 500 times the current annual estimated world production rate of 1.97 Mt (the average world production of the past 5 years). About 250 Mt, or 25%, of the estimated 1-Gt world reserve is in the United States (Founie, 2006). The world reserve base was estimated by the U.S. Bureau of Mines in 1985 to be almost 2 Gt (Meisinger, 1985). The world's reputed leading producing district is near Lompoc. A resource estimate based just on the dimensions of the those deposits, suggests that diatomite from those deposits alone could meet the world's current needs for centuries. Information on reserves is difficult to calculate because some companies are reluctant to release proprietary data and data, from some nations is inadequate. Huge deposits also occur in China (Lu, 1998, p. 53).

World Review

For 2005, world output was estimated to be 2.02 Mt, 4% higher than that of 2004 (table 5). Chinese, Japanese, and Mexican diatomite production increased by 4% to 5% in 2005 when compared with the previous year. The United States was the leading producer, consumer, and exporter of diatomite and accounted for 32% of total world production, followed by China with 20%, Denmark with 12% (all moler products), Japan with 6%, the Commonwealth of Independent States and France each with 4%, and Mexico with 3%. Small amounts of diatomite were produced in 24 other countries.

Outlook

The increase in production was small, and the diatomite market grew only slightly in 2005. Much of the growth was owing to a growing use of diatomite as a lightweight component and as a pozzolan in the cement industry. The diatomite market is expected to be stable for the next several years, with the export market continuing to remain strong. A change in the amount of diatomite used as a filtration medium would be linked to changes in the markets of products that use diatomite in their filtering process. Diatomite use in filtration of human blood plasma was expected to continue expanding. Increased energy costs and possible global overcapacity, however, may be impediments to future expansion. The past concerns of encroachments into filter applications by more advanced technologies using carbon membranes, ceramics, and polymers were not a major concern to diatomite producers in 2005 because cost factors and tradition, particularly in the brewing and wine industries, precluded changing to substitutes. Disposal of diatomite waste, however, continued to be a problem not fully resolved by recycling. The association problem of free-crystalline silica with diatomite, particularly when calcined, was expected to continue to be a concern. Finally, with the large domestic and world reserve bases and small change in demand, it appears that there will be adequate supplies of diatomite for the foreseeable future.

The purchase of World Minerals and the bankruptcy filing by EaglePicher did not apparently affect diatomite production in 2005; production by these two companies is expected to continue and may even expand.

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TABLE 1
DIATOMITE SOLD OR USED, BY PRODUCERS IN THE UNITED STATES[1]

(Thousand metric tons and thousand dollars)

	2004	2005
Domestic production, sales:		
Quantity	620	653
Value	177,000	179,000

[1]Data are rounded to no more than three significant digits.

TABLE 2
DIATOMITE SOLD OR USED, BY MAJOR USE[1]

(Percentage of U.S. production)

	2004	2005
Absorbents	7	7
Fillers	12	11
Filtration	75	75
Insulation	2	2
Other[2]	3	5

[1]Includes exports.
[2]Includes silicate admixtures (especially for cement) and unspecified uses.

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TABLE 3
AVERAGE VALUE PER METRIC TON OF DIATOMITE, BY MAJOR USE[1]

	2004	2005
Absorbents	$72.94	$30.68
Fillers	360.65	382.27
Filtration	269.25	261.79
Insulation	43.41	44.09
Other[2]	1,020.00	652.34
Weighted average	285.72	274.02

[1]Based on unrounded data.
[2]Includes absorbents and silicate admixtures.

TABLE 4
U.S. EXPORTS OF DIATOMITE[1, 2]

(Thousand metric tons and thousand dollars)

Year	Quantity	Value[3]
2004	143	53,700
2005	142	60,400

[1]Harmonized Tariff System (HTS) heading 2512.00.0000, natural and straight-calcined grades, but in practice probably includes an undetermined quantity of flux-calcined product HTS heading 3806.90.2000.
[2]Data are rounded to no more than three significant digits.
[3]Free alongside ship U.S. customs value.

Source: U.S. Census Bureau.

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TABLE 5

DIATOMITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country	2001	2002	2003[e]	2004[e]	2005[e]
Algeria	3	3	3 [3]	3 [3]	3
Argentina	17	23	36 [r, 3]	8 [r, p]	10
Australia[e]	20	20	20	20	20
Brazil, marketable[e]	7 [r]	6 [r,]	7 [r]	7 [r]	8
Chile	23	30	26 [3]	30 [r, 3]	30
China[e]	350	370	380	390	410
Colombia[e]	4	4	4	4	4
Commonwealth of Independent States[e, 4]	80	80	80	80	80
Costa Rica	26	26 [e]	26 [3]	27 [r]	27
Czech Republic	83	28	41	33 [r]	35
Denmark[e, 5]	231	230	232	233	234
Ethiopia[6]	(8) [e]	1 [e]	1 [3]	2 [3]	2
France[e]	85 [r]	80 [r]	80 [r, 3]	75	75
Germany	50	54	55 [3]	54	55
Iceland	30	26 [r]	28 [r, 3]	28 [r, 3]	29
Iran[7]	-- [r]	2 [r]	10 [r, 3]	8 [r, 3]	8
Italy[e]	25	25	25	25	25
Japan	129 [r]	124 [r]	112 [r, 3]	125 [r, 3]	130
Kenya	(8)	1	(8) [r]	(8) [r, 3]	(8)
Korea, Republic of	28	21	16 [3]	2 [r, 3]	2
Macedonia[e]	5	5	5	5	5
Mexico	69	62	53 [r, 3]	59 [r, 3]	62 [3]
Mozambique	--	--	-- [3]	3	5
Peru[e]	35	35	35	35	35
Poland	1	1	1	1 [3]	1
Portugal[e]	(8) [r]	(8) [r]	(8) [r]	(8) [r]	(8)
Romania	10	20	31 [3]	30	30
Spain[e, 9]	35	35	35	35	35
Thailand	1	1	1 [3]	1 [3]	1
Turkey[e]	10	10	10	10	10
United States[10]	644	624	599 [3]	620 [3]	653 [3]
Total	2,000 [r]	1,950 [r]	1,950 [r]	1,950 [r]	2,020

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown. Purity and moisture content are generally not reported or estimated.

[2]Table includes data available through April 4, 2006.

[3]Reported figure.

[4]Information is inadequate for formulation of reliable estimates for individual countries.

[5]Data represent "extracted moler" (reported cubic meters times 1.5). Contains about 30% clay.

[6]Year ending July 7 of that stated.

[7]Data are for year beginning March 21 of that stated.

[8]Less than ½ unit.

[9]Includes tripoli.

[10]Sold or used by producers.

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EXPLOSIVES

By Deborah A. Kramer

Domestic survey tables were prepared by Nicholas A. Muniz, statistical assistant.

In 2005, U.S. explosives sales were 3.20 million metric tons (Mt), a 27% increase from those in 2004; sales of explosives were reported in all States except Delaware. Much of this increase is believed to be attributable to more accurate reporting by the manufacturers. Coal mining, with 65% of total consumption, continued to be the dominant use for explosives in the United States. Wyoming, West Virginia, and Kentucky, in descending order, led the Nation in coal production, accounting for 60% of the total. These States also were the leading explosives-consuming States, accounting for 45% of total U.S. explosives sales.

Legislation and Government Programs

As of October 1, 2005, the National Institute of Occupational Safety and Health (NIOSH) discontinued its explosives research program, which had been transferred to the agency from the U.S. Bureau of Mines in 1996. The NIOSH claimed that the small number of serious accidents involving the use of explosives in occupational settings was the reason it could no longer justify supporting explosives research. The loss of the NIOSH's explosives program leaves the United States without a Government laboratory responsible for commercial explosives health and safety research. This also affects the Mine Safety and Health Administration's (MSHA) permissible explosive approval program; the NIOSH was responsible for testing permissibles (Institute of Makers of Explosives, 2005§[1]).

In July, the Secure Handling of Ammonium Nitrate Act was introduced in the House of Representatives (H.R. 3197). It mirrored a bill introduced in the Senate (S. 1141). The Act would give the U.S. Department of Homeland Security (DHS) the authority to regulate entities and individuals that produce, sell, or distribute ammonium nitrate-base fertilizer. This bill also would allow the DHS, working with the U.S. Department of Agriculture, to develop regulations to create a registry of those who handle ammonium nitrate-base fertilizer. Only facilities and people registered with the DHS would be able to legally access ammonium nitrate-base fertilizer. Anyone purchasing ammonium nitrate would be required to have a registration number, and retailers would be required to keep records of ammonium nitrate sales for at least 3 years. At yearend, both bills still were in committee (Fertilizer Institute, The, 2005§).

The U.S. Department of Justice amended the regulations of the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF) to require licensed importers to mark all explosive materials they import for sale or distribution. Licensed manufacturers are required to place identification markings on explosive materials manufactured in the United States. Similar marking requirements, however, did not exist for imported explosive materials. Identification markings are needed on explosives to help ensure that these materials can be effectively traced for criminal enforcement purposes. Although the ATF does not have regulatory oversight over foreign manufacturers, it does have authority over licensed importers of explosive materials. This new rule will impose identification requirements on licensed importers of explosive materials that are similar to the marking requirements imposed on domestic manufacturers. The rule became effective on July 26 (U.S. Department of Justice, Bureau of Alcohol, Tobacco, Firearms, and Explosives, 2005).

Production

Sales of ammonium-nitrate-base explosives (blasting agents and oxidizers) were 3.17 Mt, which was a 28% increase from those of 2004, and accounted for 99% of U.S. industrial explosives sales. Most of the increase in explosives sales was believed to result from more accurate reporting by the manufacturers. Sales of permissibles increased by 28%, and sales of other high explosives decreased by 23% (table 1). Figure 1 shows how sales for consumption have changed since 1996. Sales for consumption data have been revised on the basis of revised data from the Federal Reserve Board and the U.S. Census Bureau.

Companies contributing data to this report, including those that are not members of the Institute of Makers of Explosives (IME), are as follows:

- Accurate Energetic Systems LLC
- Apache Nitrogen Products Inc.*[2]
- Austin Powder Co.
- Baker Atlas International
- Daveyfire Inc.
- Douglas Explosives Inc.
- Dyno Nobel Inc.
- Energetic Systems Inc.
- Ensign-Bickford Co., The
- ETI Canada
- D.C. Guelich Explosives Co.
- Jet Research Center
- Mining Services International Corp.
- Nelson Brothers LLC *
- Orica USA Inc.
- Owen Oil Tools Inc.
- St. Lawrence Explosives Corp.
- Schlumberger Perforating Center
- Senex Explosives Inc.
- Titan Specialties Ltd.
- Vet's Explosives Inc.
- Viking Explosives and Supply Co.
- W.A. Murphy Inc.

[1]References that include a section mark (§) are found in the Internet References Cited section.

[2]Companies denoted by an asterisk are not members of the IME.

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Terra Industries Inc. announced that it had entered into a renewable 10-year supply contract with Orica USA Inc. to supply the company with industrial-grade ammonium nitrate and ammonium nitrate solution. Terra planned to invest $10 million to modify the smaller of two ammonium nitrate production towers at its Yazoo City, MS, production plant to enable it to produce industrial-grade product. This modification was expected to be completed by September 2006, at which point Terra Industries would begin supplying the industrial-grade ammonium nitrate to Orica USA; the ammonium nitrate solution would be supplied at the start of the agreement in July 2005 (Green Markets, 2005c).

Rising security costs and concerns prompted some companies to stop marketing agricultural-grade ammonium nitrate. In January, J.R. Simplot Co. announced that it would discontinue marketing fertilizer-grade ammonium nitrate to its United States and Canadian customers after the spring planting season. As a result of this decision, the company's Brandon, Manitoba, Canada, plant, which supplied these markets, would increase production of its other products—urea ammonium nitrate solutions and urea—and produce only a small quantity of ammonium nitrate for blending (Green Markets, 2005b). In July, Agrium Inc. announced that it would discontinue production and sales of fertilizer-grade ammonium nitrate. The company produced ammonium nitrate at its Beatrice, NE, facility (Green Markets, 2005a). Air Products and Chemicals Inc. was looking for a buyer for its Pace, FL, ammonium nitrate production facility. Yara North America Inc. announced that it would stop selling fertilizer-grade ammonium nitrate in California because of security concerns and rising costs associated with security regulations. By yearend, the only firms producing fertilizer-grade ammonium nitrate in the United States were El Dorado Chemical Co. and Terra Industries.

In September, The Ensign-Bickford Co. announced that its Spanish Fork, UT, explosives manufacturing plant would close no later than February 28, 2006. The company had decided to get out of the commercial explosives business in 2003 and had tried unsuccessfully to sell the Spanish Fork plant. The company expected to continue to manage shutdown and cleanup activities (International Society of Explosives Engineers, 2005§). Dyno Nobel ASA had purchased Ensign Bickford's explosives assets in 2003, with the exception of the Spanish Fork plant.

Consumption

Coal mining, with 65% of total explosives consumption, remained the principal application for explosives in the United States (table 2). In 2005, U.S. coal production increased by 1.9% to a record level of 1.03 Mt, according to preliminary data from the U.S. Department of Energy, Energy Information Administration (EIA). Coal production in all three regions (Appalachian, interior, and western) increased in 2005. The tonnage increase in the western region accounted for about 56% of the total U.S. tonnage increase (Freme, 2006§). Wyoming, West Virginia, and Kentucky, in descending order, led the Nation in coal production, accounting for 60% of the total. These States also were the leading explosives-consuming States.

Quarrying and nonmetal mining, the second ranked consuming industry, accounted for 14% of total explosives sales; construction, 11%; metal mining, 7%; and miscellaneous uses, 3%. Wyoming, West Virginia, Kentucky, Indiana, Virginia, and Alabama, in descending order, were the leading consuming States, with a combined total of 57% of U.S. sales (table 3).

The value of new construction in 2005 increased by 10.5% compared with that in 2004 (U.S. Census Bureau, 2006§). Based on monthly data, the seasonally adjusted industry growth rate from 2004 to 2005 for metal mining was 6.8%, and the growth rate for nonmetallic mineral mining and quarrying was 1.9% (Federal Reserve Board, 2006§).

Apparent consumption of commercial explosives used for industrial purposes in this report is defined as sales as reported to the IME. Commercial explosives imported for industrial uses were included in sales. The principal distinction between high explosives and blasting agents is their sensitivity to initiation. High explosives are cap sensitive, whereas blasting agents are not. Black powder sales were minor and were last reported in 1971. The production classifications used in this report are those adopted by the IME.

***High Explosives.*—Permissibles.**—The MSHA approved grades by brand name as originally established by NIOSH testing.

Other High Explosives.—These include all high explosives except permissibles.

Blasting Agents and Oxidizers.—These include ammonium nitrate-fuel oil (ANFO) mixtures, regardless of density; slurries, water gels, or emulsions; ANFO blends containing slurries, water gels, or emulsions; and ammonium nitrate in prilled, grained, or liquor (water solution) form. Bulk and packaged forms of these materials are contained in this category. In 2005, about 94% of the total blasting agents and oxidizers sales was in bulk form.

World Review

On November 30, a consortium of investors led by Macquarie Bank Ltd. completed its acquisition of Dyno Nobel Holding ASA for $1.7 billion from Industri Kapital Ltd. and Ensign-Bickford Industries Inc. The consortium intended to separate Dyno Nobel Holding into two parts. The consortium will retain the Australian and North American businesses and the 50% interest in the DetNet initiation systems joint venture. These entities will now make up the new Dyno Nobel Ltd., retaining the Dyno Nobel name. In a separate agreement, Orica Ltd. agreed to acquire Dyno Nobel Holding's African, Asian, European, Latin American, and Middle Eastern businesses for $685 million, subject to regulatory approvals. Completion of the consortium's acquisition of Dyno Nobel Holding was not conditional on the Orica sale. Orica expected that a number of the Dyno Nobel businesses that were acquired by Orica would be transferred within 2 months of closing, with the balance completed within 6 months (Dyno Nobel Ltd., 2005a§).

On December 29, Dyno Nobel America purchased Nitrochem Corp.'s three nitric acid plants and two ammonium nitrate plants in Maitland, Ontario, Canada. Nitrochem's principal markets were in eastern Canada and the northeastern United States. Products manufactured at the plants include nitric acid, ammonium nitrate (prills and solution), and aqua ammonia,

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which are used in explosives, nylon intermediates, drugs, pigments, and other industries (Dyno Nobel Ltd., 2006§).

Before the sale of Dyno Nobel Holdings, Russia's Ural Mining & Metallurgical Co. (UMMC) and Dyno Nobel agreed to establish a joint-venture company in the Urals region to supply explosive-related products, initiation systems, and related services to the UMMC group of mines. UMMC is the second ranked copper producer in Russia. The new company, called Dyno Nobel UMMC, would be the exclusive supplier to all UMMC-controlled mines and also would serve other third-party mines and quarries in the region. By the second quarter of 2006, the joint-venture company planned to establish two emulsion explosives plants serving the Urals region (Dyno Nobel Ltd., 2005b§).

Current Research and Technology

In a U.S. Department of the Army-wide awards program dedicated to recognizing the best technology solutions for soldiers, the Army chose the 10 winning programs for their impact on Army capabilities, inventiveness, and potential benefit outside the Army. One of the awards went to the Fido™ explosives detector. The detector, developed by the U.S. Army Research Laboratory and Nomadics Inc., is a lightweight (less than 3 pounds) integrated explosives detection system based on a sensitive amplifying fluorescent polymer. Fido™ can be handheld as a tethered sensor, mounted on a robotic platform, such as unmanned ground or aerial vehicles, or on underwater autonomous vehicles. With a new polymer developed by scientists at Massachusetts Institute of Technology, the sensitivity of Fido's™ explosives-vapor sensing has been shown to detect quantities of explosives at femtogram (10^{-15} gram) levels, which is comparable in field tests to bomb-sniffing dogs (U.S. Department of the Army, 2006§; Massachusetts Institute of Technology, Institute for Soldier Nanotechnologies, 2005§). Fido™ can be used to screen packages, vehicles, facilities, and people for traces of explosives, as well as for improvised explosive device and landmine sensing. The product's key markets are military force protection and homeland security. The U.S. military is currently using Fido™ in field tests for a variety of applications related to improvised explosive devices.

Although the primary goal of the University of Wisconsin-Madison's inertial electrostatic containment fusion experiment is to produce more energy than it expends, modifications to the device may help to detect C-4 (a plasticized version of the high explosive cyclotrimethylenetrinitramine, also known as RDX). By altering the device's cathode size, geometry, and material composition, the researchers increased neutron-production rates from the fusion reaction. With 95% accuracy in repeated simulations, the scientists were able to detect the nitrogen in C-4 using prompt gamma neutron activation analysis techniques. The thermal neutrons interact with the nuclei—primarily nitrogen and hydrogen—of the C-4 and emit a characteristic gamma ray. From the nitrogen, the gamma ray is 10.83 megavolts (MV); from the hydrogen, it is 2.22 MV. The researchers planned to develop an improved system that will include additional detectors and an alternate configuration to increase the number of 10.83 MV gamma rays it can detect (University of Wisconsin-Madison, 2005§).

Researchers at the University of South Florida's Center for Ocean Technology developed a sensor that can detect the explosive 2,4,6-trinitrotoluene (TNT) in a marine environment. The newly developed sensor is a self-contained system that uses an electrochemical electrode to sense for trace TNT. Researchers took into account the fact that TNT in seawater undergoes biodegradation in a number of different ways and accounted for those processes in developing the sensor. The sensor has been designed to detect several kinds of commercial and military explosives while riding on a remotely controlled surface vehicle that wirelessly transmits data to a handheld computer. The system has been tested in the field under a number of conditions, including turbulent waters (University of South Florida, 2005§).

Spire Corp. won a $750,000 Phase II small business innovation research contract from the DHS Advanced Research Projects Agency to develop a portable terahertz-based detection imager. The device will contain a quantum cascade laser source that emits terahertz radiation and a detector that will be able to detect the reflected signal, which reveals weapons and explosives concealed under clothing or in nonmetal containers. Phase I of the project identified the atmospheric windows for terahertz transmission and selected the best candidate for the imaging system (Compound Semiconductor.net, 2005§).

Outlook

According to the EIA, in 2006, U.S. coal production is expected to grow by 1.0% from that in 2005 and increase by another 1.2% in 2007. Power sector consumption of coal, which is the leading consuming industry of coal, would continue to increase in response to high natural gas and oil prices. Most of the increased production was projected to come from the western region, which has less overburden than coal in the Appalachian or interior regions (U.S. Department of Energy, Energy Information Administration, 2006§). Based on the coal production projections, explosives consumption is expected to increase in 2006 and 2007, although at a slower rate than coal production because there would be less overburden to remove.

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TABLE 1
SALIENT STATISTICS OF INDUSTRIAL EXPLOSIVES AND BLASTING AGENTS SOLD FOR CONSUMPTION IN THE UNITED STATES[1]

(Metric tons)

Class	2004	2005
Permissibles	970	1,240
Other high explosives	41,700	32,100
Blasting agents and oxidizers	2,480,000	3,170,000
Total	2,520,000	3,200,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: Institute of Makers of Explosives.

TABLE 2
ESTIMATED INDUSTRIAL EXPLOSIVES AND BLASTING AGENTS SOLD FOR CONSUMPTION IN THE UNITED STATES, BY CLASS AND USE[1, 2]

(Thousand metric tons)

Class	Coal mining	Quarrying and nonmetal mining	Metal mining	Construction work	All other purposes	Total
2004:						
Permissibles	1	(3)	(3)	(3)	--	1
Other high explosives	5	17	1	16	3	42
Blasting agents and oxidizers	1,650 r	344 r	178 r	244 r	62 r	2,480
Total	1,660 r	361 r	179 r	260 r	65 r	2,520
2005:						
Permissibles	1	(3)	(3)	(3)	--	1
Other high explosives	4	13	1	13	1	32
Blasting agents and oxidizers	2,080	435	236	339	77	3,170
Total	2,090	448	237	352	78	3,200

rRevised. -- Zero.

[1]Distribution of industrial explosives and blasting agents by consuming industry estimated from indices of industrial production and economies as reported by the U.S. Department of Energy, the Federal Reserve Board, the U.S. Department of Transportation, and the U.S. Census Bureau.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Less than ½ unit.

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TABLE 3

INDUSTRIAL EXPLOSIVES AND BLASTING AGENTS SOLD FOR CONSUMPTION IN THE UNITED STATES, BY STATE AND CLASS[1]

(Metric tons)

State	2004				2005			
	Fixed high explosives				Fixed high explosives			
	Permissibles	Other high explosives	Blasting agents and oxidizers	Total	Permissibles	Other high explosives	Blasting agents and oxidizers	Total
Alabama	21	582	65,400	66,000	3	474	128,000	128,000
Alaska	--	541	17,500	18,000	--	759	16,800	17,500
Arizona	39	412	58,700	59,200	50	211	77,000	77,300
Arkansas	--	256	22,900	23,200	--	131	33,200	33,300
California	--	724	26,900	27,700	--	883	29,400	30,300
Colorado	88	1,530	22,800	24,400	15	1,250	21,300	22,600
Connecticut	--	420	5,490	5,910	--	449	5,650	6,100
Delaware	--	105	432	64	--	--	--	--
Florida	--	263	32,900	33,100	--	156	41,200	41,400
Georgia	22	1,200	46,500	47,700	--	1,380	44,400	45,800
Hawaii	--	15	1,330	1,350	--	5	1,260	1,260
Idaho	--	175	7,980	8,160	--	119	9,730	9,850
Illinois	--	837	49,400	50,200	1	405	53,700	54,100
Indiana	(2)	1,440	197,000	199,000	1	1,050	264,000	265,000
Iowa	--	1,250	16,100	17,300	2	802	19,800	20,600
Kansas	--	447	13,300	13,700	--	246	8,380	8,620
Kentucky	549	2,220	327,000	330,000	639	1,370	368,000	370,000
Louisiana	--	467	3,870	4,340	--	235	4,090	4,320
Maine	--	104	2,910	3,020	--	193	2,550	2,740
Maryland[3]	3	325	13,800	14,100	2	322	11,400	11,800
Massachusetts	4	532	7,820	8,360	1	444	7,130	7,570
Michigan	--	111	26,800	26,900	--	64	31,500	31,600
Minnesota	--	112	35,100	35,200	--	90	41,100	41,200
Mississippi	--	458	64	522	--	451	37	488
Missouri	--	3,340	60,500	63,800	61	2,530	84,900	87,500
Montana	--	2,280	53,900	56,200	--	1,880	67,500	69,400
Nebraska	--	240	929	1,170	--	44	1,230	1,270
Nevada	--	2,800	39,800	42,600	--	1,400	43,000	44,400
New Hampshire	--	635	11,400	12,000	--	620	12,100	12,800
New Jersey	1	396	5,890	6,280	--	196	5,730	5,930
New Mexico	--	279	25,100	25,400	1	313	39,300	39,600
New York	12	682	15,800	16,500	13	685	6,160	6,850
North Carolina	--	921	32,900	33,800	--	862	35,600	36,500
North Dakota	--	2	3,700	3,710	--	12	3,370	3,380
Ohio	1	818	58,100	58,900	(2)	582	45,500	46,100
Oklahoma	(2)	356	28,300	28,700	(2)	298	30,200	30,500
Oregon	--	1,430	7,280	8,710	--	2,250	8,300	10,600
Pennsylvania	77	2,950	101,000	104,000	43	1,540	120,000	122,000
Rhode Island	(2)	50	1,190	1,240	--	60	644	704
South Carolina	--	221	5,830	6,050	--	369	6,960	7,320
South Dakota	--	3	4,290	4,300	--	4	5,480	5,490
Tennessee	1	1,740	33,600	35,300	1	1,150	38,300	39,400
Texas	19	1,080	83,300	84,400	42	1,030	105,000	106,000
Utah	44	337	43,000	43,400	69	203	50,700	50,900
Vermont	(2)	153	1,150	1,300	--	89	1,140	1,230
Virginia	15	3,630	126,000	130,000	217	2,140	154,000	156,000
Washington	--	772	20,300	21,100	1	904	16,100	17,000
West Virginia	73	667	347,000	348,000	70	673	473,000	474,000
Wisconsin	--	807	14,000	14,800	--	388	14,500	14,900
Wyoming	--	559	350,000	351,000	--	348	582,000	582,000
Total	970	41,700	2,480,000	2,520,000	1,240	32,100	3,170,000	3,200,000

See footnotes at end of table.

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TABLE 3—Continued

INDUSTRIAL EXPLOSIVES AND BLASTING AGENTS SOLD FOR CONSUMPTION IN THE UNITED STATES, BY STATE AND CLASS[1]

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

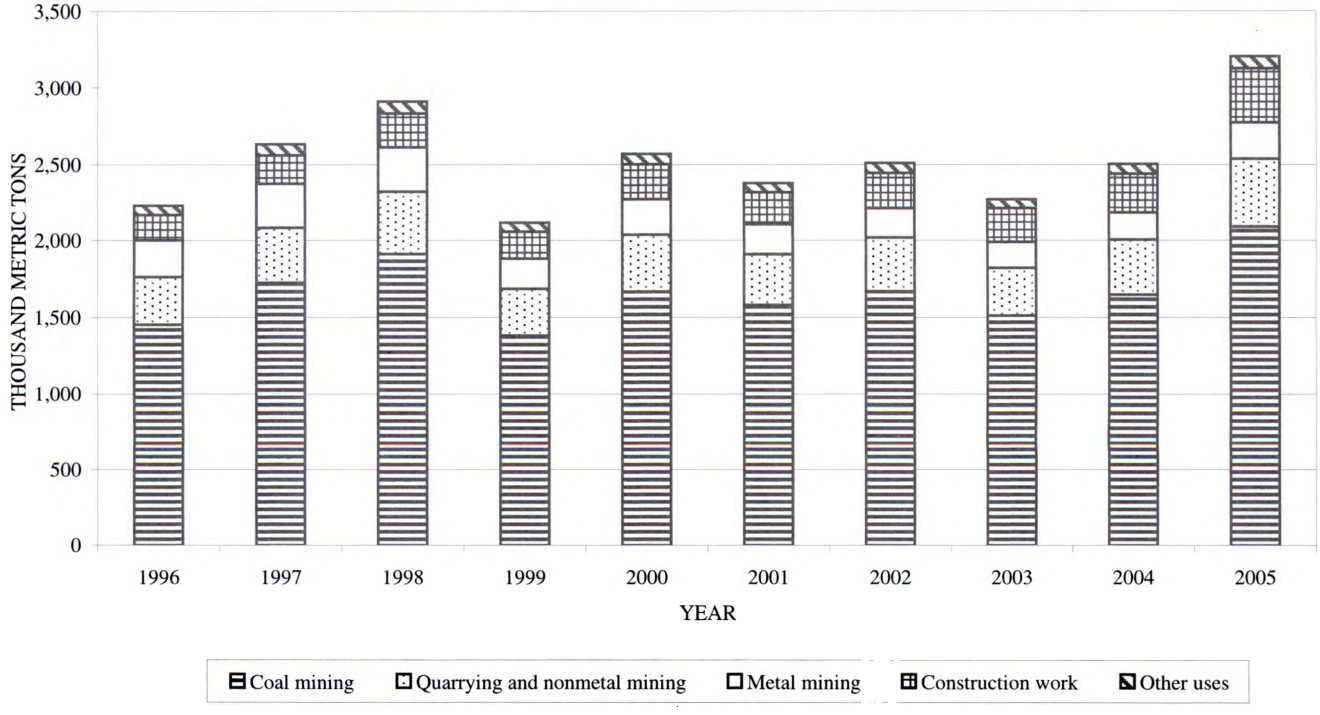
[2]Less than ½ unit.

[3]Includes the District of Columbia.

Source: Institute of Makers of Explosives.

FIGURE 1

SALES FOR CONSUMPTION OF U.S. INDUSTRIAL EXPLOSIVES



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Feldspar and Nepheline Syenite

By Michael J. Potter

Domestic survey data and tables were prepared by Hoa P. Phamdang, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

In 2005, U.S. feldspar production was estimated to have decreased by about 3% to 750,000 metric tons (t) valued at $43 million. Exports of feldspar increased by 58% to 15,200 t valued at $2.07 million, and imports increased by 27% to 26,200 t valued at $1.7 million. There was no U.S. production of nepheline syenite, and imports of nepheline syenite (from Canada) decreased by 3% to 340,000 t valued at $33.8 million. Apparent consumption of feldspar and nepheline syenite combined was 1.1 million metric tons (Mt). World production of feldspar was 12.9 Mt, slightly higher than in 2004.

This report includes information on feldspar, nepheline syenite, and aplite (one U.S. producer). Trade data in this report are from the U.S. Census Bureau.

Feldspar

Production.—Data on domestic production and sales and use of feldspar were collected by the U.S. Geological Survey (USGS) by means of a voluntary survey. Of the 12 known beneficiation facilities, 6 responded with production data by the canvass closeout date. These respondents represented about 58% of the 2005 production tonnages listed in tables 1 and 2. Production for the remaining operations was estimated from prior-year production levels. Feldspar was mined in seven States, which were, in descending order of estimated output, North Carolina, Virginia, California, Oklahoma, Georgia, Idaho, and South Dakota. North Carolina accounted for about almost 50% of the total. Nine U.S. companies mined feldspar and operated 12 beneficiation facilities—4 in North Carolina, 3 in California, and 1 in each of the 5 remaining States listed above (table 3).

For the purposes of research and development, i-minerals inc., which was not yet in production, shipped a 40-t bulk sample of potassium feldspar and quartz material from its property in northwest Idaho to North Carolina State University's Minerals Research Laboratory in Asheville, NC. There, pilot-scale processing of the material was to be performed to produce a potassium feldspar glaze product for potential sales to the ceramics industry (i-minerals inc., 2005§[1]).

Consumption.—Feldspar is used in glassmaking, ceramics, and to some extent as a filler/extender in paint, plastics, and rubber. In glassmaking, alumina from feldspar improves product hardness, durability, and resistance to chemical corrosion. In ceramics, the alkalis in feldspar (calcium oxide, potassium oxide, and sodium oxide) act as a flux, lowering the melting temperature of a mixture. Fluxes melt at an early stage in the firing process, forming a glassy matrix that bonds together the other components of the system (Roskill Information Services Ltd., 2002, p. 184). Of the domestic feldspar sold or used, an estimated 63% by tonnage went into the manufacture of glass, including glass containers and glass fiber. Pottery (including electrical insulators, sanitaryware, tableware, and tile) and other uses, such as fillers, accounted for the remaining 37% (table 4). The value of total feldspar sold or used in table 4 is higher than the feldspar production value listed in tables 1 and 2 because the table 4 value represents the final marketed feldspar product.

U.S. shipments of glass containers, the leading end use of feldspar, increased by 1% in 2005 (U.S. Census Bureau, 2006a§). Feldspar use was also reflected in glass fiber for home insulation, sanitaryware, and tile. New U.S. housing starts were about 6% higher than in 2004 (U.S. Census Bureau, 2006b§). However, U.S. imports of sanitaryware and tile have captured a major portion of the U.S. markets. Narrow-neck beer bottles accounted for the largest segment in glass container demand. Cullet (recycled glass) was used in manufacturing most glass containers, but the amount handled and blended varies significantly from one glass plant to another (Freas, 2006).

The bathroom is becoming more of a centerpiece in the home in design and color. For example, a German manufacturer uses innovative production and glazing techniques to replicate the look of pebbles in sink basins, toilets, and corresponding accessories. A U.S. company has a new toilet design that is tankless and uses a quiet 0.2-horsepower electric pump fully enclosed within the toilet bowl that provides a powerful flush using just 1.6 gallons of water (Ceramic Industry, 2005c§).

StonePeak Ceramics, Inc. (a subsidiary of Italian company Graniti Fiandre Spa) opened a new porcelain tile manufacturing facility in Crossville, TN. The plant was producing glazed and unglazed porcelain tile and the company cited a strong U.S. demand for stone-look tile (Grahl, 2005§).

Foreign Trade.—U.S. feldspar exports were 15,200 t in 2005, about 58% higher than in 2004 (table 6). U.S. imports of feldspar were 26,200 t compared with 20,600 t in 2004. Turkey supplied 76%, and Mexico, 23% (table 7). Turkey has recently become the leading exporting country to the United States. The "other" category of U.S. imports in table 7 for 2005 has a high unit value and is probably material other than feldspar. The resulting total average unit value for U.S. imports for 2005 is about $65 per metric ton compared with about $46 per ton in 2004.

U.S. imports of ceramic tile composed 79% of the U.S. tile market in 2004. Italy was the leading supplier followed by Brazil. Other countries of origin were China, Columbia, Mexico, Spain, Thailand, and Venezuela (Ceramic Industry, 2005b§). Imports met about 47% of U.S. tile consumption in 1980 and 51% in 1990 (Tile Council of North America, Inc., undated§).

World Industry Structure.—Feldspar was produced in more than 50 countries. Italy was the leading producing country with an estimated 2.5 Mt of feldspathic materials in 2005, followed by Turkey with 2.2 Mt. Japan had an estimated production of

[1]References that include a section mark (§) are found in the Internet References Cited section.

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1 Mt of feldspathic minerals, including altered granite, aplite, pegmatitic feldspar, and roseki (a type of china stone). Thailand had an estimated production of 1 Mt; output was largely sodium feldspar (table 8). Although official production data were not available, China has been estimated, by some sources, to have an output of 1 million to 2 million metric tons per year (Mt/yr) (Roskill Information Services Ltd., 2002, p. 46, 90, 136).

China has had major growth in the production of sanitaryware, tableware, and tile in recent years. Other countries, including Asian countries, that also produce these products, have been affected by the Chinese competition. Such countries as Indonesia, the Philippines, and Sri Lanka have been seeking state protection, including tariff increases on imported ceramic products (King, 2005).

***World Review.*—Australia.**—Monto Minerals Ltd. continued with development of its Goondicum Industrial Minerals Project. Commercial testing of a bulk sample of feldspar was said to have been successfully completed at a glass manufacturer in the Philippines. An additional 2 to 3 t of material for fine grinding was slated to be processed for customer trials in paint manufacture (Monto Minerals Ltd., 2006§).

Czech Republic.—With an output of more than 400,000 metric tons per year (t/yr), the country is a significant producer of feldspar. Feldspar is among the country's most important industrial minerals in terms of production and regional exports. Feldspathic sand and gravel and leucocratic granitoid deposits are the most important feldspar sources at present. The mineral is consumed in the domestic ceramic and glass industries; Czech exports were 144,000 t in 2004, with Hungary, Poland, and Slovakia being the leading recipients (Stary and Kavina, 2005).

France.—Paris-based Imerys Group signed an agreement in September to acquire Denain-Anzin Mineraux Group (DAM) from Nord Est Group, a French industrial group. DAM is one of Europe's leading producers of feldspar, kaolin, mica, and quartz. The deal remained subject to the approval of regulatory authorities (O'Driscoll, 2005a).

Nepheline Syenite

In glass and ceramics manufacture, nepheline syenite, like feldspar, provides alkalis that act as a flux to lower the melting temperature of a glass or ceramic mixture, prompting faster melting and fuel savings. In glass, nepheline syenite also supplies alumina, which gives improved thermal endurance, increased chemical durability, and increased resistance to scratching and breaking.

***World Review.*—Canada.**—Canada's sole nepheline syenite producer, Unimin Canada, Ltd., operated two plants at its Blue Mountain, Ontario, deposit, about 175 kilometers northeast of Toronto, Ontario. Production of marketable nepheline syenite was estimated to be about 710,000 t in 2004. For 2002 (latest data), the British Geological Survey (2004, p. 308) reported output to be 721,000 t. Detailed end-use data in recent years have not been available, but historically, end uses have been in glass, ceramics, and pigments and fillers. Total nepheline syenite exports were 476,000 t in 2004. The leading recipients were the United States, 350,000 t; Italy, 54,000 t; the Netherlands, 39,000 t; and Spain, 20,000 t (United Nations Statistics Division, undated§).

China.—Fineton Industrial Minerals Ltd. of Hong Kong was planning to expand capacity of its Jiulong Mining (Anyang) Co. Ltd. nepheline syenite operation in Anyang, Henan Province, to 100,000 t/yr in 2006. Fineton initially looked for markets in Europe because of resistance of consumers in China to switching from feldspar to nepheline syenite, a less known product. In 2003 and 2004, exports were primarily to Italy and Spain. In 2005, the company again began concentrating on markets in the Asia-Pacific region because of anticipated faster growth there (O'Driscoll, 2005b).

Norway.—North Cape Minerals AS produced nepheline syenite from an underground mine on the arctic island of Stjernoya; output was estimated to be about 340,000 t in 2004. End-use data for this material have not been available in recent years, but uses in the past have included glass (including amber glass), ceramics, and fillers. In 2004, total exports were 336,000 t. The leading recipients were Poland, 65,000 t; Germany, 58,000 t; the United Kingdom, 55,000 t; the Netherlands, 38,000 t; France, 32,000 t; and Spain, 24,000 t (United Nations Statistics Division, undated§).

Outlook

Glass containers and whiteware ceramics, especially sanitaryware and tiles, continue to be major end uses of feldspar and nepheline syenite. Glass containers have continued to face competition from plastic and metal containers. Also, the use of cullet (recycled glass) in glassmaking and making glass containers more lightweight by reducing wall thickness have moderated the consumption of glass raw materials, including feldspar and nepheline syenite. However, the glass container market appears to be stable to slowly growing (Freas, 2006). Glass manufacturers have reported increased glass container demand in such developing regions as China and Latin America (Ceramic Industry, 2005a§).

Chinese companies have been a major source of feldspar for domestic ceramic use and for other Southeast Asia countries. Turkey has been a major supplier to European countries and could possibly develop markets elsewhere. As feldspar use increases in the ceramic tile industry, ceramic-producing regions in China, Italy, Latin America, Southeast Asia, and Spain have been and are projected to continue to be major factors in feldspathic consumption (Roskill Information Services Ltd., 2002, p. 202-203, 301).

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TABLE 1

SALIENT FELDSPAR AND NEPHELINE SYENITE STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Produced, feldspar:						
Quantity[e, 2]	metric tons	800,000	790,000	800,000	770,000	750,000[3]
Value[e, 2]	thousands	$44,100	$42,800	$43,400	$44,000[3]	$43,000[3]
Exports, feldspar:[4]						
Quantity	metric tons	5,460	9,590	8,950	9,630	15,200
Value[5]	thousands	$1,410	$1,370	$1,310	$1,420	$2,070
Imports for consumption:[4]						
Feldspar:						
Quantity	metric tons	6,140	5,450	7,980	20,600	26,200
Value[6]	thousands	$749	$775	$1,020	$944	$1,700
Nepheline syenite:[7]						
Quantity	metric tons	336,000	333,000	308,000	350,000	340,000
Value[6]	thousands	$24,100	$26,100	$28,200	$29,000	$33,800
Consumption, apparent[e, 8]	thousand metric tons	1,140	1,120	1,110	1,130	1,100
World, production[e, 9]	do.	11,800[r]	12,000[r]	12,200[r]	12,600[r]	12,900[e]

[e]Estimated. [r]Revised.

[1]Data are rounded to no more than three significant digits.

[2]Includes hand-cobbed feldspar, flotation-concentrate feldspar, feldspar in feldspar-quartz mixtures, and aplite; may differ from sales in table 4.

[3]Rounded to two significant digits.

[4]Source: U.S. Census Bureau.

[5]Free alongside ship (f.a.s.) value.

[6]Customs value.

[7]No nepheline syenite produced in the United States for glass and ceramic use.

[8]Production plus imports minus exports. Includes feldspar and nepheline syenite.

[9]Feldspar only.

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TABLE 2
ESTIMATED FELDSPAR PRODUCTION IN THE UNITED STATES[1]

(Thousand metric tons and thousand dollars)

	Flotation concentrate		Other[2]		Total	
Year	Quantity	Value	Quantity	Value	Quantity	Value
2004	340	19,000	430	25,000	770	44,000
2005	350	19,000	400	23,000	750	43,000

[1]Data are rounded to two significant digits; may not add to totals shown.
[2]Includes hand-cobbed feldspar, feldspar-quartz mixtures (feldspar content), and aplite; excludes nepheline syenite.

TABLE 3
U.S. PRODUCERS OF FELDSPAR IN 2005

Company	Location	Product
APAC Arkansas Inc.	Muskogee, OK	Feldspar-quartz mixture.
Feldspar Corp., The	Monticello, GA	Potassium feldspar.
Do.	Spruce Pine, NC	Sodium-potassium feldspar; feldspar-quartz mixture.
Granite Rock Co.	Felton, CA	Feldspar-quartz mixture.
Kings Mountain Mining LLC	Kings Mountain, NC	Do.
K-T Feldspar Corp.	Spruce Pine, NC	Sodium-potassium feldspar; feldspar-quartz mixture.
Pacer Corp.	Custer, SD	Potassium feldspar.
PW Gillibrand Co.	Simi Valley, CA	Feldspar-quartz mixture.
Unimin Corp.	Byron, CA	Do.
Do.	Emmett, ID	Do.
Do.	Spruce Pine, NC	Sodium-potassium feldspar.
U.S. Silica Co.	Montpelier, VA	Aplite.

TABLE 4
ESTIMATED FELDSPAR SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE[1,2]

(Thousand metric tons and thousand dollars)

	2004		2005	
Use	Quantity	Value	Quantity	Value
Glass[3]	500 r	27,000	470	27,000
Pottery and miscellaneous	270	19,000	270	18,000
Total	770 r	46,000 [4]	750	45,000 [4]

rRevised.
[1]Data are rounded to two significant digits; may not add to totals shown.
[2]Includes hand-cobbed feldspar, flotation-concentrate feldspar, feldspar in feldspar-quartz mixtures, and aplite. feldspar-quartz mixtures, and aplite.
[3]Includes container glass, glass fiber, and other glass.
[4]Represents final marketable product; value higher than that listed in tables 1 and 2.

TABLE 5
PRICES FOR U.S. FELDSPAR, YEAREND 2005

(Dollars per metric ton)

	Price[1]
Ceramic grade:	
170 to 200 mesh, sodium	66-83
200 mesh, potassium	138
Glass grade:	
30 mesh, sodium	44-57
80 mesh, potassium	94-99

[1]Bulk, ex-works, United States.

Source: Industrial Minerals, no. 459, December 2005, p. 70.

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TABLE 6
U.S. EXPORTS OF FELDSPAR, BY COUNTRY[1]

(Metric tons and dollars)

Country	2004		2005	
	Quantity	Value[2]	Quantity	Value[2]
Canada	1,110	182,000	1,030	196,000
Colombia	883	194,000	1,410	320,000
Costa Rica	1,590	205,000	2,820	358,000
Dominican Republic	370	79,100	128	19,000
Guatemala	632	70,200	306	40,500
Italy	1,680	166,000	2,350	343,000
Mexico	768	140,000	1,100	184,000
Nicaragua	2,180	280,000	2,210	298,000
Panama	--	--	3,140	174,000
Other	258	55,400	725	135,000
Total	9,470	1,370,000	15,200	2,070,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship value.

Source: U.S. Census Bureau.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF FELDSPAR, BY COUNTRY[1, 2]

(Metric tons and dollars)

Country	2004		2005	
	Quantity	Value[3]	Quantity	Value[3]
Mexico	5,890	588,000	6,030	579,000
Turkey	14,700	308,000	20,000	780,000
Other	71	48,400	194	343,000
Total	20,600	944,000	26,200	1,700,000

[1]Excludes nepheline syenite, which is listed in table 1.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Customs value.

Source: U.S. Census Bureau.

TABLE 8
FELDSPAR: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Argentina	48,522	82,642	90,854 [r]	104,631 [r]	105,000
Australia, includes nepheline syenite[e]	50,000	50,000	50,000	50,000	60,000
Brazil, processed	69,209 [r, 4]	45,194 [r]	53,476 [r]	115,952 [r]	120,000 [5]
Bulgaria	23,000	34,000	35,000	35,000 [e]	35,000
Burma[e, 6]	10,000	10,000	10,000	10,000	10,000
Chile	2,867	3,069	6,690	4,838 [r]	5,000
Colombia[e]	55,000	93,452 [5]	100,000	100,000	100,000
Cuba[e]	7,000	7,000	7,000	7,000	7,000
Czech Republic	373,000	401,000 [e]	421,000	400,000 [e]	400,000
Ecuador	60,688	31,254	44,268 [r]	48,700 [r]	49,000 [5]

See footnotes at end of table.

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TABLE 8—Continued

FELDSPAR: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Egypt[e]	300,000	350,000	350,000	350,000	350,000
Ethiopia[7]	250 [r, e]	230 [r, e]	208 [r]	361 [r]	370
Finland	34,289	46,715	48,353 [r]	57,149 [r]	60,000
France, crude[e]	650,000	650,000	650,000	650,000	650,000
Germany[e]	500,000 [r]	500,000 [r]	500,000 [r]	500,000 [r]	500,000
Greece[e]	95,000	95,000	95,000	95,000	95,000
Guatemala	6,809	11,843	9,320	4,473 [r]	4,500
India[e]	110,000	110,000	150,000	150,000	150,000
Iran	204,078	191,316	242,898 [r]	252,713 [r]	250,000
Italy[e]	2,600,000	2,500,000	2,500,000	2,500,000	2,500,000
Japan, includes aplite[e]	1,330,000 [r]	1,140,000 [r]	1,010,000 [r]	900,000 [r]	1,000,000
Jordan	611	530	13,057 [r]	13,060 [r]	14,000
Kenya[e]	73 [5]	75	75	80 [r]	80
Korea, Republic of	467,161 [r]	519,125 [r]	477,012	541,788 [r]	540,000
Macedonia	20,449	21,000	21,000 [e]	20,000 [e]	20,000
Madagascar[e]	3	3	3	3	3
Malaysia	40,509	30,819	42,662 [r]	79,220 [r]	80,000
Mexico	329,591	332,101	346,315	364,315 [r]	349,109 [5]
Morocco	8,979	19,401	20,000 [e]	20,000 [e]	20,000
Nigeria	1,811	1,800	1,800 [e]	1,700 [e]	1,700
Norway[e]	73,000	75,000	74,000	75,000	76,000
Pakistan[e]	44,000	45,000	47,000	47,000	50,000
Peru	4,253	6,018	7,349	6,005 [r]	7,000
Philippines[e]	33,122 [5]	30,000	30,000	30,000	30,000
Poland[8]	220,600	293,000	320,000	300,000 [e]	300,000
Portugal[e]	120,000	120,000	120,000	120,000	120,000
Romania	43,047	51,959	71,717	70,000 [e]	70,000
Russia[e]	45,000	45,000	45,000	45,000	45,000
Serbia and Montenegro[e]	4,451 [5]	4,500	4,500	4,500	4,000
Slovakia[e]	6,000	4,000	5,000	5,000	5,000
South Africa	66,736	57,197	57,738 [r]	53,044 [r]	56,574 [5]
Spain, includes pegmatite[e]	450,000	450,000	450,000	450,000	450,000
Sri Lanka	27,438	28,866	32,586	33,000 [e]	34,000
Sweden, salable, crude and ground[e]	40,450 [5]	40,000	41,000	42,000	43,000
Thailand	710,543	783,733	824,990	1,001,053 [r]	1,000,000
Turkey	1,510,293	1,766,387	1,862,310	1,983,336 [r]	2,200,000
United Kingdom, china stone[e]	2,000	2,000	2,000	2,000	2,000
United States	800,000	790,000	800,000	770,000	750,000 [5, 9]
Uruguay	4,722	1,550 [r]	2,450 [r]	1,950 [r]	2,000
Uzbekistan[e]	4,300	4,300	4,300	4,300	4,300
Venezuela	142,000	147,000	149,000	176,000 [r]	180,000
Zimbabwe	1,055	728	816	1	--
Total	11,800,000 [r]	12,000,000 [r]	12,200,000 [r]	12,600,000 [r]	12,900,000

[e]Estimated. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through April 24, 2006.

[3]In addition to the countries listed, China, Namibia, the United Arab Emirates, and Yemen may produce feldspar, but output is not officially reported; available general information is inadequate for the formulation of reliable estimates of output levels.

[4]Source: Departamento Nacional de Produção Mineral (DNPM) [Brazilian Bureau of Mines], Feldspar, Mineral Summary 2001, accessed May 13, 2003, at URL http://www.dnpm.gov.br/dnpmengl.html.

[5]Reported figure.

[6]Data are for fiscal years beginning April 1 of year stated.

[7]Data are for fiscal years ending July 7 of year stated.

[8]Of the amounts shown, the dedicated feldspar mine production accounts for only part of total feldspar production.

[9]Rounded to two significant digits.

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FERROALLOYS

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Ferroalloys are alloys of iron used to add one or more chemical elements into molten metal, usually during steelmaking. Ferroalloys impart distinctive qualities to steel and cast iron or serve important functions during production. The leading ferroalloy-producing countries in 2005 were, in decreasing order of production, China, South Africa, Ukraine, Russia, and Kazakhstan (table 6). These countries accounted for 70% of global ferroalloy production.

The ferroalloy industry is closely associated with the iron and steel industry, the leading consumer of its products. World production of bulk ferroalloys—chromium, manganese, and silicon—was estimated to be 24.4 million metric tons (Mt) in 2005, a 3% increase compared with the revised figure for 2004. U.S. bulk ferroalloy reported consumption in 2005 was 0.9 Mt of manganese and silicon ferroalloys (table 2) and 0.3 Mt of contained chromium in ferrochromium (table 3). Compared with that of 2004, ferrochromium consumption decreased by 4%, ferromanganese (including silicomanganese), by 13%, and ferrosilicon, by 1%. On a gross weight basis, U.S. total ferroalloy production (table 6), decreased by 3%; total ferroalloy imports (table 5) increased by less than 1% and exports (table 5) increased almost 150%, which resulted in a net import decrease of more than 2%. These percentages were reflected in a slight slowdown in the U.S. alloyed steel industry, counterbalanced by growth in worldwide steel production during 2005.

Manganese is an essential alloying element in the production of virtually all steels and is important to the production of cast iron. Manganese neutralizes the harmful effect of sulfur. Silicon is primarily used as an alloying element to deoxidize steel. It is also an alloying element in the production of cast iron. Boron, chromium, cobalt, columbium (niobium), copper, molybdenum, nickel, phosphorus, titanium, tungsten, vanadium, zirconium, and the rare-earth elements are some of the other alloying elements used for the characteristics they provide to steels and cast irons (Brown and Murphy, 1985, p. 265).

U.S. domestic production of ferroalloys was relatively low other than silicon and manganese compared with that of the major ferroalloy-producing countries. On the basis of silicon content, U.S. ferrosilicon net production, which included miscellaneous silicon alloys, was 52% of U.S. ferrosilicon apparent consumption in 2005. On the basis of silicon, U.S. silicon metal net production, excluding semiconductor-grade material, was 52% of U.S. silicon metal apparent consumption in 2005.

The trend in countries that produce economically competitive mineral resources is toward increased production of value-added products, such as ferroalloys. U.S. production of ferroalloys is unlikely to expand because the economics of development of U.S. mineral resources for most of the ferroalloy metals are not competitive in the world market. Domestic ferroalloy production is in decline, as evidenced by the shutdown of ferronickel and common ferrochromium grades by 1999. In both cases, production ceased owing to low-grade resources, reliance on imported ore for feedstock, and high production costs. Ferrosilicon and manganese ferroalloy production has generally trended downward in the past 5 years with ferrosilicon production in 2005 14% lower than that in 2001.

Ferrochromium

In 2005, the major world chromite ore-producing countries were South Africa (more than 7 Mt), India (more than 3 Mt), and Kazakhstan (more than 3 Mt). More than 90% of chromite ore was smelted in electric arc furnaces to produce ferrochromium for the metallurgical industry. The major world ferrochromium-producing countries were South Africa (more than 2.5 Mt) and Kazakhstan (more than 1 Mt). China, India, and Russia each produced in excess of 0.5 Mt of ferrochromium. Most of the 6.6 Mt of ferrochromium produced globally was consumed in the manufacture of stainless steel. Europe (primarily Western Europe and Scandinavia including Belgium, Finland, France, Germany, Italy, Spain, Sweden, and the United Kingdom), Asia (China, Japan, the Republic of Korea, and Taiwan), and North and South America (Brazil and the United States)—the major stainless steel producing areas of the world—accounted for about 80% of world stainless steel production. World stainless steel production exceeded 24 Mt in 2005 and was expected to reach about 27 Mt in 2006.

The Western World ferrochromium industry developed in close proximity to the stainless steel industry. However, the closing of ferrochromium facilities in historically stainless steel-producing areas has resulted in the migration of ferrochromium production to areas where chromite is mined. China deviates from this model because its ferrochromium industry preceded its stainless steel industry. The Soviet Union deviated from this model because ferrochromium plants were located for political reasons. The world chromium industry in 2005 operated with production capacity in excess of demand. Ferrochromium production increased by 0.4 Mt from 2001 to 2002, by more than 1 Mt from 2002 to 2003, by more than 0.5 Mt from 2003 to 2004, and decreased slightly from 2004 to 2005. Ferrochromium production increased by nearly 2 Mt, or more than 40%, during those years. During the same time period, stainless steel production increased to 24 Mt from 19 Mt, representing a growth in consumption of 1 Mt of contained chromium.

In response to growth in demand and in anticipation of further increases, new ferrochromium-producing plants were under construction or planned in Kazakhstan and South Africa. Four

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industry trends were evolving—ferrochromium was being increasingly produced using environmentally friendly, energy- and recovery-efficient, prereduction, closed-furnace processes; chromium was being recovered more often from ferrochromium slag; the ferrochromium and stainless steel production industries were consolidating ownership; and strategic alliances were being formed between those two industries.

Ferromanganese

Manganese ferroalloys in various grades of ferromanganese and silicomanganese provide a key ingredient for steelmaking (Matricardi and Downing, 1995, p. 970). In 2005, most of the U.S. supply was imported. The leading foreign source of ferromanganese and silicomanganese, on a gross weight basis, was South Africa, whose exports of manganese ferroalloys to the United States were greater than those of the next five major exporting countries combined (Australia, China, Mexico, Norway, and Romania). Manganese ferroalloys were produced domestically mainly at a plant near Marietta, OH, which was owned by France's Eramet Group. Some silicomanganese production came from the Highlanders Alloys LLC plant at New Haven, WV; the company reportedly shut down a furnace in April after restarting it in October 2004, resumed production in August, and then shut down again in October and November (Ryan's Notes, 2005a, b). In 2005, the Eramet Group, Ukrainian producer Nikopol Ferroalloys Plant, and BHP Billiton plc of the United Kingdom accounted for a significant portion of the world's production of manganese ferroalloys. In addition to its U.S. plant, the Eramet Group produced from plants in China, France, Italy, and Norway, while BHP Billiton owned plants in Australia and South Africa. China was the leading producer of manganese ferroalloys, with an output almost twice as great as that of the next three major producers, Brazil, South Africa and Ukraine, combined (table 6).

Ferromolybdenum

Chile, China, and the United States accounted for about 79% of world production of molybdenite ore in 2005. Other significant molybdenite ore-producing countries, including Canada, Mexico, and Peru supplied an additional 16% of world production. Molybdenite concentrates are roasted to form molybdic oxide which can be converted into ferromolybdenum, molybdenum chemicals, or metal. About 46% of the molybdenum consumed in the United States was in the form of molybdic oxides, and about 26% was as ferromolybdenum. Although the United States was the leading molybdenum-producing country in the world, it imported more than 84% of its ferromolybdenum requirements in 2005. The steel industry accounted for about 84% of all molybdenum consumed in the United States in 2005, principally in the production of stainless and full alloy steels.

Ferronickel

The major ferronickel-producing countries in 2005 were, in descending order of gross weight output, Japan, New Caledonia, and Colombia with each country producing greater than 100,000 t of ferronickel. These three countries accounted for than 62% of world production. Greece, Ukraine, the Dominican Republic, and Venezuela, in descending order of gross weight output, all produced between 50,000 and 100,000 t of ferronickel, accounting for an additional 28%. Key producing companies included Anglo American Plc, BHP Billiton Group, Eramet Group, Falconbridge Ltd., Hyuga Smelting Co. Ltd., Larco G.M.M. S.A., and Pacific Metals Co., Ltd.

At Cerro Matoso (Colombia), Doniambo (New Caledonia), and several other smelters, primary ferronickel was obtained by first calcining the iron- and nickel-bearing laterite ore in a kiln and then smelting the calcined ore in an electric furnace. In Austria and Russia, secondary ferronickel was produced in relatively small amounts by melting nickel-bearing scrap in an electric furnace and upgrading the melt with nickel cathode. Most of the world's ferronickel operations were operating at full capacity in 2005 in order to meet strong demand from stainless steel producers.

In the United States, the steel industry accounted for virtually all the primary ferronickel consumed in 2005, with more than 99% used in stainless and heat-resistant steels. No primary ferronickel was produced in the United States in 2005. Almost all U.S. ferronickel exports were either re-exports or material upgraded for specialty purposes. U.S. ferronickel consumption in 2005 was 3% less than that of 2004 owing to a global ferronickel shortfall, with scrap and nickel cathode being used as substitutes. On a gross weight basis, ferronickel net imports were 48,600 t with an import- to-export ratio of 341 to 1.

Falconbridge Ltd., involved in a takeover bid from Inco Limited (Canada) at yearend 2005, and its joint-venture partners were still planning to construct a ferronickel smelter at Koniambo on the main island of New Caledonia. The partners had applied for the necessary regulatory permits and were finalizing a financial support package with the French Government. The Koniambo smelter would have a capacity of 54,000 metric tons per year of nickel in ferronickel and would use lateritic ores from the Koniambo massif as feedstock. At yearend 2005, Eramet Group lost a court battle to take over the Koniambo nickel project. Eramet claimed that Falconbridge had not upheld the terms of a 1998 agreement regarding the development of the project (Reuters, 2005§[1]).

GlobeStar Mining Corporation (Canada) controlled 70 square kilometers and began exploration for nickel laterites in the vicinity of Cerro Maimon in the Dominican Republic. Some of the concessions were relatively close to the Falcondo nickel laterite mine and ferronickel smelter (GlobeStar Mining Corporation, 2005§). In 2005, Falcondo processed 3.8 Mt of ore grading 1.2% nickel.

Ferrosilicon

Silicon ferroalloy demand is driven by cast iron and steel production, where silicon alloys are used as deoxidizers (Dosaj, 1997, p. 1115). On the basis of silicon content, U.S. net

[1]References that include a section mark (§) are found in the Internet References Cited section.

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production of silicon ferroalloys (ferrosilicon and miscellaneous silicon alloys) and silicon metal decreased by 4% to 243,000 metric tons (t) from the revised figure of 249,000 t in 2004. On a gross weight basis, U.S. net production of silicon ferroalloys and metal in 2005 decreased by 3% compared with that of 2004 (table 6).

China was estimated to be the world's leading producer of ferrosilicon, with production greater than that of the rest of the world combined and almost three times that of the next two major producing countries, Norway and Russia, combined. In 2005, most silicon metal was used as an alloying agent with aluminum and in the production of chemicals, especially silicones. Some silicon metal was also used as an alloying agent with iron.

Ferrotitanium

Titanium is used in steelmaking for deoxidation, grain-size control, and carbon and nitrogen control and stabilization. During steelmaking, titanium is usually introduced as ferrotitanium because of its lower melting temperature and higher density compared with those of titanium scrap. World ferrotitanium production capacity is led by, in descending order, the United Kingdom, Russia, Japan, and the United States. In 2005, domestic producers of ferrotitanium were Global Titanium, Inc. (Detroit, MI) and Galt Alloys Inc. (North Canton, OH). Producers of interstitial-free, stainless, and high-strength low-alloy steels are the major consumers of titanium within the steel industry.

In 2005, increased demand for titanium metal by commercial aerospace and military markets combined with demand for ferrotitanium for steel production exceeded the available supply of metal. As a result, ferrotitanium prices dramatically increased. The yearend price for ferrotitanium with 70% contained titanium was about $9.00 per pound, a 41% increase compared with the yearend price of 2004. U.S. imports of ferrotitanium and ferrosilicon titanium were 16,900 t, a 143% increase compared with those of 2004.

Ferrotungsten

Tungsten is an important alloying element in high-speed and other tool steels, and is used to a lesser extent in some stainless and structural steels. Tungsten can be added to steel melts as ferrotungsten, which is a master alloy containing between 75% and 80% tungsten; tungsten melting base, which is a master alloy containing up to 36% tungsten; tungsten metal scrap; or scheelite ore concentrates (Lassner and Schubert, 1999, p. 307-312; Roskill Information Services Ltd., 2003, p. 106, 109, 119, 130).

In 2005, world ferrotungsten production was dominated by China, which produced 11,100 t, gross weight (Juqiu, 2006, p. 5, 9). Inadequate supplies of tungsten concentrates within China, combined with increased demand for tungsten materials in China and elsewhere, resulted in steep increases in the prices of tungsten concentrates and downstream materials, including ferrotungsten. The Platts Metals Week price for ferrotungsten rose from $12 to $13 per kilogram contained tungsten at the beginning of the year to $32 to $34 per kilogram contained tungsten at yearend.

In 2005, National Defense Stockpile shipments of ferrotungsten increased to 262 t contained tungsten compared with 41 t shipped in 2004, as the stockpile's supply of ferrotungsten was sold off. U.S. ferrotungsten imports and reported consumption were similar to those of 2004. Ferrotungsten exports decreased significantly to 29 t contained tungsten from 99 t exported in 2004.

Ferrovanadium

The major vanadium-producing countries in 2005 were China and South Africa, accounting for 72% of world production, with Russia, the other significant vanadium-producing country, accounting for an additional 26%. In these three countries, vanadium is primarily recovered from titanium-bearing magnetite ore processed to produce liquid pig iron. The process produces a slag containing 20% to 24% vanadium pentoxide, which can be further processed to 40% to 50% vanadium-content ferrovanadium.

In 2005, there was no primary production of vanadium oxides in the United States. Rather, vanadium oxides were recovered from ashes, petroleum residues, and poisoned refinery catalysts. Vanadium oxides were used to produce catalysts, chemicals, and 75% to 80% vanadium-content ferrovanadium.

The domestic steel industry accounted for 93% of U.S. vanadium consumption in 2005, principally in carbon, full alloy and high-strength, low-alloy steels. Of the vanadium consumed, 84% was ferrovanadium, and the United States imported 100% of its ferrovanadium requirements in 2005.

In 2005, the production of vanadium increased in China, Russia, and South Africa to offset the permanent closures of the Windimurra Mine in Australia and the VanTec Mine in South Africa in 2004. Ferrovanadium imports increased dramatically from the Czech Republic as they became the primary converter of Russian-origin vanadium pentoxide into ferrovanadium. Production from petroleum-base vanadium recovery (ashes, catalysts, residues) continued to increase.

Outlook

Substitutes, principally alloy scrap and oxide (for some ferroalloys), have gained moderately on ferroalloy use per ton of steel produced during the past 20 years. A decline in unit ferroalloy consumption is significant during the long term for the ferroalloy industry because it would moderate any increase in ferroalloy consumption resulting from increased steel production. This general decline in unit consumption of the major ferroalloys in steelmaking has been caused by a combination of factors, including changes in availability, price, and technology.

Growing U.S. customer needs for alloy and stainless steel for many applications have been and will continue to be a strong positive influence on the demand for ferroalloys. The steel industry will continue to improve process technology, reducing raw material needs and developing steels with lower alloying metal content with equal or better performance, while

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lowering material costs. Many stainless steel applications have no acceptable substitutes, and their key constituents, chromium and nickel, are essential. Technology and industry practices will continue to find more innovative uses for ferroalloys, resulting in strong demand for ferroalloy metals used in steel for construction, the chemical industry, transportation, and household appliances. This is expected to more than offset any reduction in unit consumption. Competition from substitute materials, such as plastics and nonferrous metals, especially in the transportation sector, will be strong, but ferroalloys are expected to remain competitive for many years through the use of lightweight, high-strength steel (Sibley and others, 2001, p. 40).

Chromium, manganese, silicon, and other ferroalloy metals are discussed in more detail, including domestic data coverage and outlook and U.S. Government stockpile, in the respective mineral commodity chapters in the U.S. Geological Survey Minerals Yearbook, volume I, Metals and Minerals.

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TABLE 1
GOVERNMENT INVENTORY OF FERROALLOYS, DECEMBER 31, 2005[1, 2]

(Metric tons of alloys unless otherwise specified)

Alloy	Inventory
Ferrochromium:	
High-carbon	318,000
Low-carbon	171,000
Ferromanganese, high carbon	612,000
Ferrotungsten, contained tungsten	(3)

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Data are uncommitted inventory.
[3]The last of the ferrotungsten was sold off in 2005.

Source: Defense National Stockpile Center.

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TABLE 2

REPORTED U.S. CONSUMPTION OF FERROALLOYS AS ALLOYING ELEMENTS BY END USE IN 2005[1, 2]

(Metric tons of alloys unless otherwise specified)

End use	FeB	Manganese		FeP	FeSi	FeTi
		FeMn	SiMn			
Steel:						
Carbon and high-strength low-alloy	681	235,000	55,900	4,230	19,000 [3]	4,610
Stainless and heat-resisting	200	10,100	13,600	153	51,000 [3]	3,370
Other alloy	105	22,600	19,400	836	7,430 [3]	50
Tool	--	(3)	(3)	--	29,800	106
Unspecified	--	2,980	736	(4)	36,600 [5]	--
Total steel	986	271,000	89,600	5,220	144,000	8,130
Cast irons	--	7,260	440	1,560	96,800 [5]	17
Superalloys	36	(6)	--	(7)	279 [5, 7]	1,310
Alloys (excluding alloy steels and superalloys)	420	17,800	2,980	(7)	59,300 [5]	1,500
Miscellaneous and unspecified	--	(6)	(8)	--	179,000	--
Grand total	1,440	293,000	93,000	6,770	479,000	11,000
Total 2004	1,420	335,000	110,000	6,600	484,000 [r]	10,200
Percentage of 2004	101	87	84	103	99	107
Consumer stocks, December 31	1,220	18,300	4,800 [9]	1,120	16,300	1,020

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]FeB, ferroboron, including other boron materials; FeMn, ferromanganese, including manganese metal and other manganese alloys; SiMn, silicomanganese; FeP, ferrophosphorus, including other phosphorus materials; FeSi, ferrosilicon, including silicon metal, silvery pig iron, silicon carbide, and inoculant alloys; FeTi, ferrotitanium, including titanium scrap and other titanium materials.

[3]All or part included with "Steel, unspecified."

[4]Included with 'Steel, other alloy."

[5]Part included with "Miscellaneous and unspecified."

[6]Included with "Alloys (excluding alloy steels and superalloys)."

[7]All or part included with "Cast irons."

[8]All or part withheld to avoid disclosing company proprietary data.

[9]Consumer and producer stock.

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TABLE 3

REPORTED U.S. CONSUMPTION OF FERROALLOYS AS ALLOYING ELEMENTS BY END USE IN 2005[1, 2]

(Metric tons of contained elements unless otherwise specified)

End use	FeCr	FeMo	FeNb	FeNi	FeV	FeW
Steel:						
Carbon and high-strength low-alloy	3,870 [3]	518	2,390	--	2,150	(4)
Stainless and heat-resisting	205,000	766	562	13,200	60	(4)
Other alloy	17,000 [5]	2,590	(6)	W	1,010	(4)
Tool	3,250	W	(6)	--	402	(4)
Unspecified	W	--	--	--	--	(4)
Total	229,000	3,870	2,950	13,200	3,620	250
Cast irons	W	736	W	--	W	--
Superalloys	12,600	23	1,220	--	36	(4)
Alloys (excluding alloy steels and superalloys)	1,390	96	W	W	W	(4)
Miscellaneous and unspecified	13,400 [7]	91	3	117	259	--
Grand total	257,000	4,816	4,170	13,300	3,910	250
Total 2004	268,000	4,700 r	3,650 r	13,700 r	4,060	248
Percentage of 2004	96	102	114	97	96	101
Consumer stocks, December 31	8,600	604	NA	944	326	24

rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]FeCr, ferrochromium, including other chromium ferroalloys and chromium metal; FeMo, ferromolybdenum, including calcium molybdate; FeNb, ferrocolumbium, including nickel columbium; FeNi, ferronickel; FeV, ferrovanadium, including other vanadium-carbon-iron ferroalloys; and FeW, ferrotungsten.

[3]All or part included with "Steel, other alloy."

[4]Included with "Steel, total."

[5]Includes full alloy and high-strength low-alloy steel.

[6]Included with "Carbon and high-strength low-alloy."

[7]Includes cast irons, electrical steel, and unspecified uses.

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TABLE 4
FERROALLOY PRICES IN 2005

	High	Low	Average[1]
Chromium:			
Ferrochromium:			
0.05% carbon[2]	126.00	108.00	118.00
0.10% carbon[2]	118.00	91.00	104.47
0.15% carbon[2]	110.00	83.00	100.03
Over 4% carbon:			
50-55% chromium[2]	77.00	59.00	68.40
60-65% chromium[2]	77.00	52.00	67.32
Manganese:			
Medium-carbon ferromanganese[2]	82.00	44.00	59.41
Standard-grade ferromanganese[3]	950.00	500.00	638.15
Silicomanganese[4]	43.00	29.00	34.73
Molybdenum:			
Ferromolybdenum[5]	43.00	23.50	36.65
Molybdenum oxide[5]	40.00	22.25	31.79
Silicon:			
50% ferrosilicon[2]	68.00	47.00	55.00
75% ferrosilicon[2]	56.00	41.00	48.03
Silicon metal[5]	82.00	69.00	76.18
Vanadium, ferrovanadium[5]	61.00	21.00	32.96

[1]Annual time-weighted average.
[2]Cents per pound of contained element.
[3]Dollars per long ton.
[4]Cents per pound.
[5]Dollars per pound of contained element.

Sources: American Metal Market, Platts Metals Week, and Ryan's Notes.

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TABLE 5

U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF FERROALLOYS AND FERROALLOY METALS IN 2005[1]

Alloy	Imports			Exports		
	Gross weight (metric tons)	Contained weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Contained weight (metric tons)	Value (thousands)
Ferroalloys:						
Chromium ferroalloys:						
Ferrochromium containing:						
More than 4% carbon	398,000	232,000	$303,000	30,700	20,100	$31,100
Not more than 4% carbon	XX	XX	XX	5,460	3,540	7,560
More than 0.5% but not more than 3% carbon	3,530	2,300	4,330	XX	XX	XX
Not more than 0.5% carbon	43,000	29,300	68,500	XX	XX	XX
Ferrochromium-silicon	33,700	14,100	31,600	147	51	186
Total	478,000	278,000	408,000	36,300	23,700	38,900
Manganese ferroalloys:						
Ferromanganese containing:						
More than 4% carbon	162,000	126,000	90,900	XX	XX	XX
More than 2% but not more than 4% carbon	61	48	31	XX	XX	XX
More than 1% but not more than 2% carbon	60,300	48,500	63,400	XX	XX	XX
Not more than 1% carbon	32,200	26,600	45,300	XX	XX	XX
Ferromanganese, all grades	XX	XX	XX	14,400	XX	14,900
Silicomanganese	327,000	218,000	231,000	899	XX	1,220
Total	582,000	419,000	431,000	15,300	XX	16,100
Silicon ferroalloys:						
Ferrosilicon containing:						
More than 55% silicon	XX	XX	XX	9,830	5,940	9,590
More than 55% but not more than 80% silicon and more than 3% calcium	606	373	985	XX	XX	XX
Magnesium ferrosilicon	30,000	13,900	26,900	XX	XX	XX
Ferrosilicon, other[2]	259,000	183,000	187,000	3,610	1,800	3,780
Total	290,000	197,000	215,000	13,400	7,740	13,400
Other ferroalloys:						
Ferrocerium and other pyrophoric alloys and other	147	XX	2,050	XX	XX	XX
Ferrocolumbium	7,400	XX	60,000	410	XX	4,210
Ferromolybdenum	6,340	4,050	278,000	3,480	2,090	43,400
Ferronickel	48,800	19,300	185,000	143	72	520
Ferrophosphorus	12,100	XX	3,940	1,780	XX	1,150
Ferrotitanium and ferrosilicon-titanium	16,900	XX	76,700	3,630	XX	21,300
Ferrotungsten and ferrosilicon-tungsten	493	385	5,390	57	29	196
Ferrovanadium	NA	11,900	131,000	NA	504	19,300
Ferrozirconium	306	XX	675	65	XX	100
Ferroalloys, other	7,500	XX	15,000	2,200	XX	3,190
Total	99,900	XX	758,000	11,800	XX	93,400
Total ferroalloys	1,450,000	XX	1,810,000	76,800	XX	162,000
Metals:						
Chromium (total, all grades)	11,000	XX	87,700	1,020	XX	16,900
Manganese, other:						
Unwrought	31,300	XX	54,500	XX	XX	XX
Other	451	XX	1,180	XX	XX	XX
Silicon:						
Less than 99% silicon	32,800	30,300	48,500	6,760	6,560	12,700
Less than 99.99% but not less 99% silicon	122,000	120,000	187,000	1,780	1,770	4,210
Not less than 99.99% silicon	2,070	XX	131,000	14,800	XX	830,000
Total metals	200,000	XX	510,000	24,400	XX	864,000
Grand total	1,650,000	XX	2,320,000	101,000	XX	1,030,000

NA Not available. XX Not applicable.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes less than 55% silicon and greater than 80% silicon.

Source: U.S. Census Bureau.

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TABLE 6

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1, 2]

(Metric tons, gross weight)

Country, furnace type, and alloy type[3, 4, 5]	2001	2002	2003	2004[e]	2005[e]
Albania, electric furnace, ferrochromium	11,900	22,100	37,800	47,700 r, 6	35,780 6
Argentina, electric furnace:					
Ferrosilicon[e]	2,740 6	2,700	2,700	2,700	2,700
Silicomanganese[e]	5,150 6	5,000	5,000	5,000	5,000
Silicon metal[e]	8,000	8,000	8,000	8,000	8,000
Other[7]	9,925	17,289	15,000 e	15,000	15,000
Total	25,815	32,989	30,700 e	30,700	30,700
Australia, electric furnace:[e]					
Ferromanganese	115,000	115,000	115,000	115,000	120,000
Silicomanganese	135,000	135,000	135,000	135,000	140,000
Silicon metal	30,000	30,000	30,000	30,000	35,000
Total	280,000	280,000	280,000	280,000	295,000
Austria, electric furnace:[e]					
Ferronickel	3,700 r	2,500 r	3,700 r	750 r	1,000
Other	4,000	4,000	4,000	4,000	4,000
Total	7,700 r	6,500 r	7,700 r	4,750 r	5,000
Bhutan, electric furnace, ferrosilicon[e]	16,000	21,000	21,000	20,000	20,000
Bosnia and Herzegovina, electric furnace:[e]					
Ferrosilicon	1,000	1,000	1,000	1,000	1,000
Silicon metal	200	200	--	--	--
Total	1,200	1,200	1,000	1,000	1,000
Brazil, electric furnace:					
Ferrochromium[8]	110,468	164,140 r	204,339	216,277 r, 6	185,533 p, 6
Ferrochromiumsilicon	5,899	10,522	10,500	11,560 r, 6	11,600 p, 6
Ferromanganese	276,000 r	339,000 r	438,000 r	508,000 r	510,000 p
Ferronickel	17,966	19,874	19,378 r	20,338 r, 6	21,200 p
Ferrosilicon	159,345	145,910	146,000	146,000	146,000
Silicomanganese	180,235	182,731	180,200	180,000 r	108,200 p, 6
Silicon metal	112,123	133,390	133,400	133,400	133,400 p, 6
Other[e]	79,750	87,398	86,400	86,400	86,500 p
Total	941,786 r	1,082,965 r	1,218,217 r	1,301,975 r, 6	1,202,433 p, 6
Bulgaria, electric furnace:[e]					
Ferrosilicon	8,000	8,000	8,000	8,000	8,000
Other	10,000 r	10,000 r	10,000 r	10,000 r	10,000
Total	18,000 r	18,000 r	18,000 r	18,000 r	18,000
Canada, electric furnace:[e]					
Ferrosilicon	56,000	56,000	56,000	56,000	56,000
Ferrovanadium	1,000	1,000	1,000	1,000	1,000
Silicon metal	30,000	30,000	30,000	30,000	30,000
Total	87,000	87,000	87,000	87,000	87,000
Chile, electric furnace:					
Ferromanganese	2,213	--	--	--	--
Ferromolybdenum	1,740 r	3,160 r	4,070 r	5,760 r	5,800
Total	3,953 r	3,160 r	4,070 r	5,760 r	5,800
China:[e]					
Blast furnace:					
Ferromanganese	500,000	500,000	550,000	590,000 r	600,000
Other	100,000	100,000	100,000	100,000	100,000
Electric furnace:					
Ferrochromium	310,000	330,000	500,000	640,000 r	750,000
Ferromanganese	670,000	490,000	700,000	1,120,000 r	1,100,000
Ferromolybdenum	37,700	29,600	60,000 r	70,000 r	60,000
Ferrosilicon	1,320,000	1,500,000	2,200,000	3,000,000	2,800,000

See footnotes at end of table.

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TABLE 6—Continued

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1, 2]

(Metric tons, gross weight)

Country, furnace type, and alloy type[3, 4, 5]	2001	2002	2003	2004[e]	2005[e]
China—Continued:[e]					
Electric furnace—Continued:					
Silicomanganese	1,170,000	1,580,000	1,800,000	2,600,000	3,800,000
Other	392,000	310,000	461,000	800,000	1,400,000
Total	4,500,000	4,840,000	6,370,000 [r]	8,920,000 [r]	10,600,000
Colombia, electric furnace, ferronickel	91,475	111,952	111,324	113,647 [r, 6]	123,000
Croatia, electric furnace, ferrochromium[e]	361 [6]	--	--	--	--
Czech Republic, electric furnace, other[e]	1,000	1,000	1,000	1,000	1,000
Dominican Republic, electric furnace, ferronickel	60,654	58,101 [r]	69,628 [r]	75,763 [r, 6]	75,800
Egypt, electric furnace:[e]					
Ferromanganese	30,000	30,000	30,000	30,000	30,000
Ferrosilicon	55,000	55,000	55,000	55,000	55,000
Total	85,000	85,000	85,000	85,000	85,000
Finland, electric furnace, ferrochromium	236,710	248,181	250,490	264,492 [6]	234,881 [6]
France:[e]					
Blast furnace, ferromanganese	300,000	300,000	180,000	--	--
Electric furnace:					
Ferromanganese	130,000	130,000	120,000	106,000	110,000
Ferrosilicon	100,000	100,000	100,000	100,000	100,000
Silicomanganese[9]	50,000	50,000	107,000	64,000	65,000
Silicon metal	75,000	75,000	75,000	75,000	75,000
Other	65,000	65,000	65,000	65,000	65,000
Total	720,000	720,000	647,000	410,000	415,000
Georgia, electric furnace:[e]					
Ferromanganese	100 [6]	-- [6]	--	--	--
Silicomanganese	25,000	25,000	25,000	25,000	25,000
Total	25,100	25,000	25,000	25,000	25,000
Germany, electric furnace:					
Ferrochromium	19,308	20,018	18,318	24,857 [6]	22,672 [6]
Other[10]	52,700 [r]	60,000 [r]	61,700 [r]	55,000 [r]	55,000
Total	72,008 [r]	80,018 [r]	80,018 [r]	79,857 [r, 6]	77,672 [6]
Greece, electric furnace, ferronickel	88,755	97,761	95,376	96,000 [e]	95,000
Hungary, electric furnace:[e, 11]					
Ferrosilicon	7,000	7,000	7,000	7,000	7,000
Silicon metal	1,000	1,000	1,000	500	500
Total	8,000	8,000	8,000	7,500	7,500
Iceland, electric furnace, ferrosilicon	111,948	120,624	117,171 [r]	118,000 [r]	120,000
India, electric furnace:[e]					
Ferrochromium[12]	267,395 [6]	311,927 [6]	468,677 [6]	527,100 [6]	611,373 [6]
Ferrochromiumsilicon	10,000	10,000	10,000	10,000	10,000
Ferromanganese	165,000	165,000	165,000	170,000	170,000
Ferrosilicon	50,000	52,000	54,000	55,000	56,000
Silicomanganese	150,000	150,000	160,000	160,000	170,000
Other	9,000	9,000	9,000	9,000	9,000
Total	651,000	698,000	867,000	931,000	1,030,000
Indonesia, electric furnace:					
Ferromanganese[e]	12,000	12,000	12,000	12,000	12,000
Ferronickel	47,769	42,306	43,894 [r]	39,538 [r, 6]	36,690 [6]
Silicomanganese[e]	7,000	7,000	7,000	7,000	4,000
Total	66,769	61,306	62,894 [r]	58,538 [r, 6]	52,690 [6]
Iran, electric furnace:					
Ferrochromium	8,430	8,000 [r, e]	10,000 [r, e]	7,750 [r, 6]	8,000
Ferrosilicon[e]	40,000	41,700	40,297 [r, 6]	50,150 [r, 6]	50,000
Total	48,430	49,700	50,297 [r]	57,900 [r, 6]	58,000

See footnotes at end of table.

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TABLE 6—Continued

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1, 2]

(Metric tons, gross weight)

Country, furnace type, and alloy type[3, 4, 5]	2001	2002	2003	2004[e]	2005[e]
Italy, electric furnace:[e]					
Ferromanganese	40,000	40,000	40,000	40,000	40,000
Silicomanganese	90,000	90,000	90,000	90,000	90,000
Silicon metal	6,000	6,000	6,000	6,000	6,000
Other[13]	10,000	10,000	10,000	10,000	10,000
Total	146,000	146,000	146,000	146,000	146,000
Japan, electric furnace:					
Ferrochromium[14]	111,167	91,937	19,427	13,472 [r, 6]	12,367 [6]
Ferromanganese	368,293	356,717	371,831	437,389 [r, 6]	448,616 [6]
Ferronickel	367,739	370,973	369,099 [r]	374,213 [r, 6]	391,074 [6]
Silicomanganese	62,238	70,965	58,043	73,041 [r, 6]	94,725 [6]
Other[15]	12,940	12,352	10,007	12,822 [r, 6]	16,436 [6]
Total	922,377	902,944	828,407 [r]	910,937 [r, 6]	963,218 [6]
Kazakhstan, electric furnace:					
Ferrochromium	761,900	835,800	993,000	1,080,993 [r, 6]	1,156,168 [6]
Ferrochromiumsilicon	79,800	102,200	98,130	104,800 [r, 6]	97,870 [6]
Ferromanganese	5,349	2,278	1,931	2,000	2,100
Ferrosilicon	145,800	127,300	127,300	103,580 [r, 6]	104,185 [6]
Silicomanganese	141,200	164,000	178,920	155,324 [r, 6]	170,214 [6]
Other[e]	9,000	9,000	9,000	9,000	9,000
Total	1,143,049	1,240,578	1,408,281	1,455,697 [r, 6]	1,539,537 [6]
Korea, North, electric furnace:[e]					
Ferromanganese[10]	6,000	6,000	6,000	6,000	6,000
Ferrosilicon	3,000	3,000	3,000	3,000	3,000
Other	1,000	1,000	1,000	1,000	1,000
Total	10,000	10,000	10,000	10,000	10,000
Korea, Republic of, electric furnace:					
Ferromanganese	143,525	137,000 [e]	141,000	165,525 [r, 6]	165,000
Silicomanganese	101,877	94,000 [e]	90,942 [r]	82,917 [r, 6]	83,000
Other	4,452	--	--	--	--
Total	249,854	231,000 [e]	231,942 [r]	248,442 [r, 6]	248,000
Macedonia, electric furnace:[e]					
Ferronickel	10,300	17,000	19,000	18,800	28,000
Ferrosilicon	50,000	50,000	50,000	50,000	50,000
Total	60,300	67,000	69,000	68,800	78,000
Mexico, electric furnace:[16]					
Ferromanganese	60,014	38,532	55,903	72,471 [6]	89,641 [6]
Silicomanganese	74,290	73,263	81,223	103,206 [6]	104,780 [6]
Total	134,304	111,795	137,126	175,677 [6]	194,421 [6]
New Caledonia, electric furnace, ferronickel[e]	162,000	171,000	175,000	149,000 [6]	169,000
Norway, electric furnace:[e]					
Ferrochromium	82,600 [6]	61,100 [6]	--	--	--
Ferromanganese	240,000	240,000	245,000	245,000	250,000
Ferrosilicon	450,000	390,000	350,000	300,000	270,000
Silicomanganese	230,000	230,000	230,000	230,000	230,000
Silicon metal	100,000	105,000	100,000	105,000	105,000
Other[9]	15,000	15,000	15,000	15,000	15,000
Total	1,120,000	1,040,000	940,000	895,000	870,000
Peru, electric furnace, ferrosilicon[e]	600	600	600	600	600
Poland:[e]					
Blast furnace, ferromanganese	500	600	1,000 [r]	1,000 [r]	1,000
Electric furnace:					
Ferrosilicon	48,600 [6]	41,800	92,700 [r]	90,000 [r]	90,000

See footnotes at end of table.

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TABLE 6—Continued

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1, 2]

(Metric tons, gross weight)

Country, furnace type, and alloy type[3, 4, 5]	2001	2002	2003	2004[e]	2005[e]
Poland—Continued:[e]					
Electric furnace—Continued:					
Silicomanganese	20,000 [6]	7,500	-- [r]	-- [r]	--
Silicon metal	-- [r]	-- [r]	-- [r]	-- [r]	--
Total	69,100 [r, 6]	49,900 [r]	93,700 [r]	91,000 [r]	91,000
Romania, electric furnace:					
Ferromanganese	384	--	-- [e]	--	--
Ferrosilicon	5,823	--	-- [e]	--	--
Silicomanganese	71,921	84,720 [r]	141,899 [r]	194,945 [r, 6]	200,000
Total	78,128	84,720 [r]	141,899 [r]	194,945 [r, 6]	200,000
Russia:[e]					
Blast furnace:					
Ferromanganese	55,000	105,000	101,000	108,000	108,000
Ferrophosphorus	3,500	3,500	3,500	3,500	3,500
Spiegeleisen	7,000	7,000	7,000	7,000	7,000
Electric furnace:					
Ferrochromium	210,600 [6]	210,000 [6]	357,000 [6]	454,000	578,000 [6]
Ferrochromiumsilicon	4,000	4,000	4,000	4,000	4,000
Ferronickel[17]	30,000 [6]	45,000	23,500 [r]	28,700 [r]	24,100
Ferrosilicon	707,100 [6]	701,000	760,000	721,000	742,000 [6]
Ferrovanadium	18,800	15,100	8,000	13,700 [r]	12,880 [6]
Silicomanganese	124,000	127,000	83,000	143,000	145,000
Silicon metal	40,000	40,000	45,000	45,000	45,000
Other	16,200	14,900	22,000	22,000	22,000
Total	1,220,000	1,270,000	1,410,000 [r]	1,550,000 [r]	1,690,000
Saudi Arabia, electric furnace, other[e]	78,000	75,000	75,000	85,000 [r]	85,000
Slovakia, electric furnace:[e]					
Ferrochromium	5,968 [6]	5,695 [6]	1,924 [6]	1,784 [6]	867 [6]
Ferromanganese	20,000	20,000	20,000	20,000	20,000
Ferrosilicon	50,000	50,000	50,000	50,000	50,000
Silicomanganese	35,000	35,000	35,000	35,000	35,000
Other	5,000	5,000	5,000 [r]	5,000 [r]	5,000
Total	116,000	116,000	112,000 [r]	112,000 [r]	111,000
Slovenia, electric furnace:[e]					
Ferrosilicon	8,000	8,000	9,000	9,000	9,000
Other[7]	200	200	--	--	--
Total	8,200	8,200	9,000	9,000	9,000
South Africa, electric furnace:					
Ferrochromium	2,141,000	2,351,122	2,813,000	2,965,000 [r, 6]	2,581,578 [6]
Ferromanganese	524,000 [r]	618,954 [r]	607,362	612,000 [r, 6]	510,000
Ferrosilicon	107,600	141,700	135,000 [r]	141,000 [r, 6]	125,000
Ferrovanadium	18,184	25,227	27,172	25,000 [r]	22,000
Silicomanganese	253,000	315,802	313,152	340,000	280,000
Silicon metal	39,400	42,500	48,500 [r]	50,500 [r, 6]	51,000
Other[e, 18]	64,000	85,000 [r]	80,000 [r]	80,000 [r]	80,000
Total	3,147,184 [r]	3,580,305 [r]	4,024,186 [r]	4,213,500 [r, 6]	3,650,000
Spain, electric furnace:[e]					
Ferromanganese	10,000	10,000	10,000	10,000	10,000
Ferrosilicon	40,000	40,000	40,000	40,000	40,000
Silicomanganese	100,000	100,000	100,000	100,000	100,000
Silicon metal	30,000	30,000	30,000	30,000	30,000
Other	5,000	5,000	5,000	5,000	5,000
Total	185,000	185,000	185,000	185,000	185,000

See footnotes at end of table.

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TABLE 6—Continued

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1, 2]

(Metric tons, gross weight)

Country, furnace type, and alloy type[3, 4, 5]	2001	2002	2003	2004[e]	2005[e]
Sweden, electric furnace:					
Ferrochromium	109,198	118,823	110,529	128,191 [6]	127,451 [6]
Ferrosilicon[e]	22,000	23,000	24,000	24,000	25,000
Total	131,198	141,823	134,529	152,191 [r, 6]	152,451 [6]
Taiwan, electric furnace, ferrosilicon	1,181	--	--	--	--
Turkey, electric furnace:					
Ferrochromium	50,735	11,200 [e]	35,393	28,701 [r, 6]	26,043 [6]
Ferrosilicon	5,895	7,245	7,000 [e]	-- [r]	--
Total	56,630	18,445	42,393	28,701 [r, 6]	26,043 [6]
Ukraine:					
Blast furnace:[e]					
Ferromanganese	85,000	85,000	85,000	79,000 [r]	30,000
Spiegeleisen	5,000	5,000	5,000	5,000	5,000
Electric furnace:					
Ferromanganese	231,000	250,617	250,000 [e]	375,990 [6]	330,000
Ferronickel[e]	41,000	31,000	-- [r]	78,000	78,000
Ferrosilicon	231,000	250,617	250,000 [e]	248,060 [6]	248,000
Silicomanganese	702,389	732,592	740,000 [e]	1,060,000 [6]	1,000,000
Other[e]	25,000	25,000	25,000	25,000	25,000
Total	1,320,389	1,379,826	1,360,000 [r, e]	1,871,050 [r, 6]	1,720,000
United States, electric furnace:					
Ferrochromium[19]	W	W	W	W	W
Ferromanganese[20]	W	W	W	W	W
Ferrosilicon[21]	191,000	182,000	148,000	171,000 [6]	164,000 [6]
Silicon metal[21]	131,000	108,000	134,000	144,000 [6]	143,000 [6]
Other[22]	W	W	W	W	W
Total	322,000	290,000	282,000	315,000 [6]	307,000 [6]
Uruguay, electric furnace, ferrosilicon[e]	200	200	200	200	200
Venezuela, electric furnace:					
Ferromanganese[e]	12,715 [6]	12,000	12,000	15,000	15,000
Ferronickel	32,300	51,700 [e]	57,300 [e]	58,000 [r]	56,300
Ferrosilicon	46,236	99,576	90,543	92,000	92,000
Silicomanganese	56,640	36,974	30,632	35,000	35,000
Total	147,891	200,250	190,475	200,000 [r]	198,000
Zimbabwe, electric furnace:					
Ferrochromium	243,584	258,164	245,200	193,077 [6]	235,000
Ferrochromiumsilicon	16,848	--	--	1,000 [r]	5,000
Total	260,432	258,164	245,200	194,077 [r, 6]	240,000
Grand total	19,200,000 [r]	20,300,000 [r]	22,800,000 [r]	26,300,000 [r]	27,600,000
Of which:					
Blast furnace:					
Ferromanganese	941,000	991,000	917,000 [r]	778,000 [r]	739,000
Spiegeleisen	12,000	12,000	12,000	12,000	12,000
Other[23]	104,000	104,000	104,000	104,000	104,000
Total, blast furnace	1,060,000	1,110,000	1,030,000 [r]	894,000 [r]	855,000
Electric furnace:					
Ferrochromium[24]	4,680,000 [r]	5,050,000 [r]	6,070,000 [r]	6,590,000 [r]	6,570,000
Ferrochromiumsilicon	117,000 [r]	127,000	123,000	131,000 [r]	128,000
Ferromanganese	3,060,000 [r]	3,010,000 [r]	3,340,000 [r]	4,060,000 [r]	3,940,000
Ferronickel	954,000	1,020,000 [r]	987,000 [r]	1,050,000 [r]	1,100,000
Ferrosilicon	4,040,000	4,230,000	4,950,000 [r]	5,660,000 [r]	5,430,000
Silicomanganese	3,780,000	4,300,000 [r]	4,590,000 [r]	5,820,000 [r]	6,880,000

See footnotes at end of table.

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TABLE 6—Continued

FERROALLOYS: WORLD PRODUCTION, BY COUNTRY, FURNACE TYPE, AND ALLOY TYPE[1, 2]

(Metric tons, gross weight)

Country, furnace type, and alloy type[3, 4, 5]	2001	2002	2003	2004[e]	2005[e]
Grand total—Continued					
Of which—Continued:					
Electric furnace—Continued:					
Silicon metal	603,000 [r]	610,000 [r]	641,000 [r]	658,000 [r]	662,000
Other[25]	947,000 [r]	896,000 [r]	1,070,000 [r]	1,430,000 [r]	2,020,000
Total, electric furnace	18,200,000 [r]	19,200,000 [r]	21,800,000 [r]	25,400,000 [r]	26,700,000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through August 16, 2006.

[3]In addition to the countries listed, Iran is believed to have produced ferromanganese, ferromolybdenum, and silicomanganese, but production information is inadequate for formulation of estimates of output levels.

[4]To the extent possible, ferroalloy production of each country has been separated according to the furnace from which production is obtained; production derived from metallothermic operation is included with electric furnace production.

[5]To the extent possible, ferroalloy production of each country has been separated to show the following individual major types of ferroalloys: ferrochromium, ferrochromiumsilicon, ferromanganese, ferronickel, ferrosilicon, silicomanganese, silicon metal, and spiegeleisen. Ferroalloys other than those listed that have been identified specifically in sources, as well as those ferroalloys not identified specifically, but which definitely exclude those listed previously in this footnote, have been reported as "Other." Where one or more of the individual ferroalloys listed separately in this footnote have been inseparable from other ferroalloys owing to a nation's reporting system, deviations are indicated by individual footnotes.

[6]Reported figure.

[7]Includes calcium-silicon.

[8]Includes high- and low-carbon ferrochromium.

[9]Includes, if any, silicospiegeleisen.

[10]Includes, if any, ferrochromiumsilicon, ferronickel, and silicomanganese.

[11]Hungary is believed to produce some blast furnace ferromanganese.

[12]Includes charge chrome and ferrochrome.

[13]Excludes calcium-silicon.

[14]Includes high- and low-carbon ferrochromium and ferrochromiumsilicon.

[15]Includes calcium-silicon, ferrocolumbium, ferromolybdenum, ferrotungsten, ferrovanadium, and other ferroalloys. Awamura Metal Industry Co. Ltd., which was the sole producer of ferrotungsten in Japan, reportedly was liquidated at the end of 2003.

[16]Salable products from Cía. Minera Autlán S.A. B. de C.V.

[17]In December 2001, Mechel OAO acquired a 79.9% interest in the South Urals Nickel Plant previously operated by Yuzhuralnikel Combine JSC. The new owner made substantial improvement to the Orsk ferronickel plant and produced a low-iron ferronickel (greater than 85% nickel).

[18]Includes, if any, ferronickel.

[19]U.S. output of ferrochromium includes chromium metal, high- and low-carbon ferrochromium, ferrochromiumsilicon, and other chromium materials.

[20]U.S. output of ferromanganese includes manganese metal and silicomanganese.

[21]Net production.

[22]May include ferroboron, ferrocolumbium, ferromolybdenum, ferrophosphorus, ferrotitanium, ferrovanadium, nickel columbium, and silvery pig iron.

[23]Includes ferrophosphorus and data contained in "Blast furnace: Other."

[24]Ferrochromium includes ferrochromiumsilicon, if any, for Japan, South Africa, and the United States.

[25]Includes ferromolybdenum and ferrovanadium.

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FLUORSPAR

By M. Michael Miller

Domestic survey data and tables were prepared by Barbara McNair, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

There was no mine production of fluorspar in the United States in 2005. The bulk of U.S. demand was supplied by imports, although supply was supplemented by sales of material from the National Defense Stockpile (NDS) and by small amounts of byproduct synthetic fluorspar produced from industrial waste streams. Byproduct fluorosilicic acid (FSA) production from some phosphoric acid producers supplemented fluorspar as a domestic source of fluorine but was not included in fluorspar production or consumption calculations. According to the U.S. Census Bureau, U.S. imports of fluorspar increased by 5%, imports of hydrofluoric acid (HF) increased by 7%, and exports of fluorspar increased by 75% compared with those in 2004 (tables 1, 4-6).

Fluorspar is used directly or indirectly to manufacture such products as aluminum, gasoline, insulating foams, plastics, refrigerants, steel, and uranium fuel. Most fluorspar consumption and trade involve either acid grade (also called acidspar), which is greater than 97% calcium fluoride (CaF_2), or subacid grade, which is 97% or less CaF_2. Subacid grade includes metallurgical and ceramic grades, and is commonly called metallurgical grade or metspar.

Legislation and Government Programs

During calendar year 2005, the Defense National Stockpile Center (DNSC) sold about 10,400 metric tons (t) of acid grade (11,444 short dry tons) and about 57,300 t of metallurgical grade (63,177 short dry tons). Unsold quantities that remain in the NDS are documented in the "Stocks" section of this report.

Production

In 2005, there was no reported mine production of fluorspar in the United States. There is no U.S. Geological Survey (USGS) data survey for synthetic fluorspar. FSA is produced as a byproduct from the processing of phosphate rock into phosphoric acid. Domestic production data for FSA were developed by the USGS from a voluntary canvass of U.S. phosphoric acid operations known to recover FSA. Of the seven FSA operations surveyed, all reported production, representing 100% of the quantity reported.

In 2005, there were three companies producing marketable byproduct FSA at phosphoric acid plants (part of a phosphate fertilizer operation). Mosaic Fertilizer (a subsidiary of The Mosaic Co.), PCS Phosphate Co., Inc. and U.S. Agri-Chemicals Corp. operated seven plants in Florida, Louisiana, and North Carolina and reported production of 50,000 t of byproduct FSA. They sold or used 49,800 t of byproduct FSA (equivalent to approximately 87,700 t of fluorspar grading 92% CaF_2). This material was valued at about $8.56 million.

FSA, which is primarily used for water fluoridation, was in short supply during the latter half of 2005. The shutdown of U.S. Agri-Chemicals' Fort Meade, FL, phosphate fertilizer plant coupled with increased demand for FSA for water fluoridation (especially in California) were the causes. Some municipalities had to scramble to locate new supplies and faced significantly higher prices (McCoy, 2005).

Additional domestic supplies of FSA are expected in 2006 when J.R. Simplot Co. begins production and distribution of FSA from its phosphate fertilizer plant in Rock Springs, WY. Initial plans call for production of 13,600 metric tons per year (t/yr), but future expansions could double production to around 27,000 t/yr. Output from the Rock Springs plant is expected to supply the municipal water fluoridation markets in the Western United States (Green Markets, 2005).

Some synthetic fluorspar was recovered as a byproduct of uranium processing, petroleum alkylation, and stainless steel pickling. The majority of the marketable product was estimated to come from uranium processing, but the actual amount of synthetic fluorspar recovered is unknown.

Hastie Mining Co. in Cave-In-Rock, IL, Oxbow Carbon and Minerals LLC in Aurora, IN, and Seaforth Mineral & Ore Co., Inc. in East Liverpool, OH, screened and dried metallurgical- and acid-grade fluorspar. These materials were either purchased from the NDS or imported from Mexico.

Environment

The consumer advocacy group U.S. Public Interest Research Group (PIRG) released a report that discussed the dangers of using HF in petroleum alkylation and identified some of the companies and refineries that use HF. The report called for refiners to switch to the use of solid acid catalysts, sulfuric acid, or modified HF (HF mixed with an additive that reduces the effective vapor pressure). The report noted that 50 of the estimated 148 refineries scattered across the United States use and store HF, which PIRG contended is a danger to more than 17 million people (Bourge, 2005).

After some HF accidents in the late 1980s, the safety of HF was studied in some detail in the early 1990s as required by the Clean Air Act Amendments of 1990. The U.S. Environmental Protection Agency (EPA) was directed to carry out a study of HF manufacturing and uses to identify potential hazards to public health and the environment. In the report, published in 1993, the EPA determined that "owners/operators can achieve an adequate margin of protection both for their workers and the surrounding community by assiduously applying existing industry standards and practices, existing regulations, and future guidance and regulations applicable to various classes of hazardous substances in various settings" (U.S. Environmental

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Protection Agency, 1993). The study and its conclusions, however, did not examine disaster scenarios related to possible terrorist attacks.

Consumption

Domestic consumption data for fluorspar were developed by the USGS from a quarterly consumption survey of three large consumers that provide data on HF and aluminum fluoride (AlF_3) consumption and four distributors that provide data on the merchant market (metallurgical and other uses). Quarterly data were received from all seven respondents, and these responses accounted for 100% of the reported consumption in table 2.

Industry practice has established three grades of fluorspar—acid grade, containing more than 97% CaF_2; ceramic grade, containing 85% to 95% CaF_2; and metallurgical grade, normally containing 60% to 85% CaF_2. Fluorspar grades are defined by the intended use, but these grades are essentially just averages. During the past several decades, there has been a general movement in the United States toward the use of higher quality fluorspar by many of the consuming industries. For example, welding rod manufacturers may use acid-grade fluorspar rather than ceramic grade, and some steel mills use ceramic or acid grade rather than metallurgical grade.

Total reported U.S. fluorspar consumption decreased by nearly 6% in 2005 compared with the revised figure for 2004. There was some significant double counting of acid grade consumed for HF and AlF_3 in 2004; revised consumption data are listed in tables 1 and 2. Consumption of acid grade for HF and AlF_3 decreased by 4.5% to 508,000 t and consumption of fluorspar for metallurgical and other uses decreased by nearly 15% (table 2).

Acid-grade fluorspar was used primarily as a feedstock in the manufacture of HF. Two companies reported fluorspar consumption for the production of HF—E.I. du Pont de Nemours & Co. Inc. (DuPont) and Honeywell International Inc. Most acid-grade fluorspar is converted to HF before consumption. In 2005, production of HF for use in manufacturing fluorocarbons accounted for the bulk of the increased consumption of acid-grade fluorspar.

The leading use of HF was for the production of a wide range of fluorocarbon chemicals, including hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), and fluoroelastomers or fluoropolymers. HCFCs and HFCs were produced by Arkema Inc. (formerly ATOFINA Chemicals Inc.), DuPont, Great Lakes Chemical Corp., Honeywell, INEOS Fluor Americas LLC, MDA Manufacturing Ltd., and Solvay Solexis Inc.

Some of the existing or potential fluorocarbon replacements for banned chlorofluorocarbons (CFCs) are HCFCs 22, 123, 124, 142b, and 225. These HCFC substitutes have ozone-depletion potentials that are much lower than those of CFCs 11, 12, and 113, and are used individually or in mixtures in home air conditioning systems, in chillers, as foam blowing agents, as solvents (in addition to perfluorocarbons and hydrofluoroethers), and as a diluent in sterilizing gas.

The HFC replacements have no ozone-depletion potential because they contain no chlorine atoms. The most successful HFC replacement compound is HFC 134a, which is primarily used as the refrigerant in automobile air conditioners, new commercial chillers and refrigerators, and as the propellant in aerosols. Other HFCs also are being produced domestically but in much smaller quantities and are being used individually or in blends as replacements for CFCs and HCFCs.

In the foam blowing market, HFCs 134a, 152a, 245fa, and 365mfc are the primary compounds that have replaced banned CFCs and HCFCs. For blowing polyurethane, the primary fluorocarbon blowing agents used in the United States are HFCs 134a and 245fa. HFC 152a has been approved for use in several types of foams but is primarily used for blowing polystyrene and polyolefin foams.

HCFCs 22, 123, and 124; HFCs 23, 125, 134a, and 227ea; and a number of other fluorine compounds have been approved by the EPA as acceptable substitutes (some subject to use restrictions) for halon 1211 as a streaming agent and for halon 1301 as a total flooding agent for fire suppression. Although the production of halons has been banned in the United States since 1993, the use of recycled halon material is allowed.

The use of HF for the manufacture of fluoroelastomers and fluoropolymers continued to display strong growth. These compounds have desirable physical and chemical properties that allow them to be used in products that include pipes, valves, seals, architectural coatings, and cookware. This strong market was one of the factors behind increased HF imports in recent years.

HF was consumed in the manufacture of uranium tetrafluoride, which was used in the process of concentrating uranium isotope 235 for use as nuclear fuel and in fission explosives. It also was used in glass etching, petroleum alkylation, stainless steel pickling, and treatment of oil and gas wells and as a cleaner and etcher in the electronics industry. HF was used as the feedstock in the manufacture of a group of inorganic fluorine chemicals that include chlorine trifluoride, lithium fluoride, sodium fluoride, stannous fluoride, sulfur hexafluoride, tungsten hexafluoride, and others that are used in decay-preventing dentifrices, dielectrics, metallurgy, mouthwashes, water fluoridation, and wood preservatives. It was used as the feedstock for producing potassium fluoride, which is the preferred fluorine source in a number of insecticides and herbicides, and in some proprietary analgesic preparations, antibiotics, and antidepressants.

Acid-grade fluorspar was used in the production of AlF_3 and cryolite (Na_3AlF_6), which are the main fluorine compounds used in aluminum smelting. In the Hall-Héroult aluminum process, alumina is dissolved in a bath that consists primarily of molten Na_3AlF_6, AlF_3, and fluorspar to allow electrolytic recovery of aluminum. In countries with strong environmental regulations, a modern aluminum smelter that uses prebaked anode technology will contain high-efficiency scrubbers that recover 96% to 99% of fluorine emissions. Fluorine losses are made up entirely by the addition of AlF_3, the majority of which will react with excess sodium from the alumina to form Na_3AlF_6. This type of smelter will consume about 20 kilograms (kg) of AlF_3 for each metric ton of aluminum produced. Plants that use the older Soderburg technology with minimal recovery of fluorine emissions have significant losses of fluorine and sodium, which are replaced by

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adding a combined 40 to 50 kg of AlF_3 and Na_3AlF_6 per ton of aluminum produced.

Minor uses of AlF_3 included its use by the ceramics industry for some body and glaze mixtures, in the production of specialty refractory products, in the manufacture of aluminum silicates, in the glass industry as a filler, as a catalyst for organic synthesis, and as an inhibitor of fermentation.

Most AlF_3 is produced directly from acid-grade fluorspar or from byproduct FSA. In 2005, Alcoa World Alumina LLC (a business unit of Alcoa Inc.) produced AlF_3 from fluorspar at Point Comfort, TX.

The aluminum fluoride industry was being investigated for possible antitrust violations or anticompetitive conduct by industry suppliers. The U.S. Department of Justice, the Competition Bureau Canada, and the Australian Competition and Consumer Commission requested documents from at least some of the major aluminum fluoride producers (Dow Jones Newswires, 2005§[1]).

The merchant fluorspar market in the United States includes sales of metallurgical and acid grade mainly to steel mills, but also to smaller markets, such as cement plants, foundries, glass and ceramics plants, and welding rod manufacturers. Depending on the size of the customer, the sales are made in rail car, truckload, and less-than-truckload quantities. In 2005, this merchant market totaled 73,500 t, which included sales of 44,500 t of acid grade (61% of the merchant market) and sales of 29,000 t of metallurgical grade (39% of the merchant market). During the past 20 to 30 years, fluorspar usage in such industries as steel and glass has declined because of product substitutions or changes in industry practices.

Acid- or ceramic-grade fluorspar was used by the ceramics industry as a flux and an opacifier in the production of flint glass, white or opal glass, and enamels. These grades also were used in welding fluxes and as a flux in the steel industry. In welding, fluxes are commercially termed "welding consumables" and are manufactured as a flux coating to electrodes, as a flux core in a wire electrode, or as powdered flux product. These products are broadly categorized as "acid," "basic," "rutile," and "cellulosic." Fluorspar is used in basic compositions where it can make up 30% to 40% of the flux composition (O'Driscoll, 2002).

Metallurgical-grade fluorspar was used primarily as a fluxing agent by the steel industry, frequently in stainless steel production. Fluorspar is added to the slag to make it more reactive by increasing its fluidity (by reducing its melting point), which also helps avoid crust formation. Reducing the melting point of the slag brings lime and other fluxes into solution to allow the absorption of impurities. Fluorspar of different grades was used in the manufacture of aluminum, brick, and glass fibers and by the foundry industry in the melt shop.

In the United States, consumption of fluorspar in metallurgical markets (mainly steel) decreased by about 19% compared with that of 2004. Consumption in this sector was 60% metallurgical grade and 40% acid grade; the bulk of the decrease was in metallurgical grade. Most of this decrease was in metallurgical.

Metallurgical- or submetallurgical-grade fluorspar is used in cement production where it acts mainly as a flux. It is added to the mix of cement raw materials before introduction to the rotary kiln. The addition of fluorspar provides a savings in thermal energy by allowing the kiln to operate at a lower temperature, thus saving fuel. It also increases the amount of tricalcium silicate produced. More tricalcium silicate results in a softer clinker product, which requires less grinding time, thus saving electrical energy. Fluorspar use, however, can damage the refractory lining in the cement kiln, and this factor has limited its use in the cement industry.

About 36,100 t of byproduct fluorosilicic acid valued at $6.44 million was sold for water fluoridation, and about 13,700 t valued at $4.13 million was sold or used for other uses. There were no sales for AlF_3 production in 2005.

Stocks

Data for stocks were available from fluorspar distributors and HF and AlF_3 producers. Known consumer and distributor stocks totaled about 131,000 t, which included 80,800 t at consumer or distributor facilities and 50,200 t purchased from the NDS but still located at NDS depots. At the end of 2005, unsold NDS material consisted of about 30,500 t of metallurgical-grade fluorspar and about 4,750 t of acid-grade fluorspar.

Transportation

The United States depends on imports for the majority of its fluorspar supply. Fluorspar is transported to customers by truck, rail, barge, and ship. Metallurgical grade is shipped routinely as lump or gravel, with the gravel passing a 75-millimeter (mm) sieve and not more than 10% by weight passing a 9.5-mm sieve. Acid grade is shipped routinely in the form of damp filtercake that contains 7% to 10% moisture to facilitate handling and to reduce dust. This moisture is removed by heating the filtercake in rotary kilns or other kinds of dryers before treating with sulfuric acid to produce HF. In recent years, most acid-grade imports have come from China and South Africa and are usually shipped by ocean freight using bulk carriers of 10,000 to 50,000 t deadweight; ships in this size range are termed "handymax." Participants negotiate freight levels, terms, and conditions. Some acid grade and ceramic grade is marketed in bags for small users and shipped by truck.

In 2005, problems were reported involving the liquefaction of acidspar flotation concentrates loaded in China. In all cases, the liquefaction resulted in severe listing with disastrous results—one ship capsized off Sri Lanka, another ship had to be abandoned (it subsequently grounded on the China coast), and a third ship was forced to seek a port of refuge (North of England P&I Club, 2006§). International shipping regulations require that concentrates or other cargoes that may liquefy should only be accepted for loading when the actual moisture content of the cargo is less than its transportable moisture limit (TML). The TML is the upper moisture limit of a cargo and is defined as 90% of its flow moisture point, which is the point at which it liquefies. It appears that some cargoes shipped from China did not have TML certificates, or, on some occasions, the reported

[1]References that include a section mark (§) are found in the Internet References Cited section.

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TML was suspect (United Kingdom Cabinet Office, Office of Public Sector Information, 1999§). It is not known if any of the lost cargoes were bound for the United States.

Maritime shipping rates are tracked by several different indices, which are differentiated by the size of ships included. The Baltic Handymax Index (BHMI) is calculated from the weighted average rates on major timecharter routes, with two trial voyage routes, as assessed by a panel of brokers. The BHMI was quite high in late winter and early spring, but decreased by about 61% between April and the beginning of August before rebounding somewhat the rest of the year, although it was still down by about 32% compared with the spring high (Hayley-Bell, 2006). The large swing in the BHMI was reflected most specifically in the range of insurance and freight costs United States fluorspar importers paid for Chinese shipments; these costs were reportedly $30 to $45 per metric ton.

Prices

At yearend, according to published prices, the average U.S. Gulf port price, cost, insurance, and freight (c.i.f.), dry basis, for Chinese acid grade increased by $35 per ton (table 3). The average price of standard Mexican acid-grade fluorspar [free on board (f.o.b.) Tampico] decreased by 19%, and the price of low-arsenic acid grade decreased by about 2%. The South African average price for acid grade (f.o.b. Durban) increased by about $25 per ton (Industrial Minerals, 2005d). Prices for metallurgical-grade fluorspar listed in table 3 were calculated from fourth-quarter statistics from the U.S. Census Bureau.

Foreign Trade

U.S. exports of fluorspar increased by 75% to 36,100 t from those of 2004 (table 4). All U.S. exports were believed to be reexports of material imported into the United States or exports of material purchased from the NDS.

In 2005, imports for consumption of fluorspar increased by 5% compared with those of 2004 (table 5). The leading suppliers of fluorspar to the United States were China (67%), Mexico (14%), South Africa (12%), and Mongolia (7%).

Some of the c.i.f. values reported by the U.S. Census Bureau for imports of acid-grade fluorspar were missing freight costs. For the specific shipments that were missing freight costs, adjustments were made by incorporating estimated freight costs derived from industry sources. These adjustments resulted in a significantly higher average value per ton for acid-grade imports than that derived from the unadjusted U.S. Census Bureau data. The average unit value, including c.i.f., was $202 per ton for acid grade and $93 per ton for metallurgical grade (table 1).

Driven by the strong fluorocarbon market, imports of HF increased by 7% to 137,000 t (table 6). Imports of synthetic and natural Na_3AlF_6 decreased by more than 19% to 3,110 t and imports of AlF_3 decreased by about 10% to 4,250 t (tables 7, 8).

There are no tariffs on fluorspar from normal-trade-relations countries. There are no tariffs on other major fluoride minerals and chemicals, such as natural or synthetic Na_3AlF_6, HF, and AlF_3.

World Review

Estimated world production increased only slightly compared with that of 2004. The leading producers, in descending order, were China, Mexico, Mongolia, and South Africa.

European Union.—The European Union's antidumping duties on imports of fluorspar from China expired on September 27, 2005. The duties, in the form of a minimum import price of €113.50 per metric ton, had been in place since the mid-1990s. Owing to the decrease in fluorspar exports from China and the significant increase in prices, fluorspar producers in Europe offered no objection to the expiration of the antidumping duties (Industrial Minerals, 2005b).

China.—The second round of bidding for fluorspar export quotas was held in June. As in the first round, 225,000 t was offered for "agreement" bidding, and 150,000 t, for "open" bidding. The average bid price for "agreement" bidding was Y464 per metric ton (about $56 per ton). Average bid prices for the "open" bidding, which are normally much higher than "agreement" bids, were not available (Mineral PriceWatch, 2005).

China's Ministry of Finance announced that, effective May 1, 2005, the 5% rebate paid to exporters of various minerals, including fluorspar, was being repealed. This followed the January 2004 reduction in the export rebate from the then rate of 12% to 15% (depending on the mineral), which "has had the net impact of increasing prices by $16-20/tonne according to traders in the country (Mineral PriceWatch, 2005)." The repeal was part of the Government's policy to restrict the amount of raw materials (such as fluorspar) exported overseas, in order to provide more material for domestic consumption.

In October, China's Ministry of Commerce issued the 2006 export quotas for various agricultural, industrial, and textile commodities, including an export quota of 710,000 t for fluorspar for 2006. This was a further reduction in the announced fluorspar quota, which had been set at 750,000 t in 2004 and 2005 and which had been as high as 1.2 million metric tons in 2000 (Beijing Antaike Information Development Co., Ltd., 2005).

France.—Aluminum producer Alcan Inc. announced that its fluorspar mining subsidiary, Société Générale de Recherches et d'Exploitations Minières (Sogerem), would cease production in the first half of 2006. Sogerem operated three mines (Burg, Montroc, and Moulinal) in the Tarn region of the Midi-Pyrenees in southern France, but the mines contained insufficient reserves for further production, and an exploration plan in the area failed to discover significant new reserves. Sogerem had produced fluorspar in the area since the early 1970s, although initial production dated from the 1940s (Industrial Minerals, 2005c).

Russia.—Russia's primary fluorspar mining company, Yaroslavsky Mining and Dressing Complex (YMDC), has new owners and a new name. In 2004, one-half of YMDC (which had been in bankruptcy since 1997) was purchased by Russian Coal (Rossugol, the state-owned Russian coal company). In early 2005, the remaining one-half was acquired by Siberian-Urals Aluminum Co. The company is now known as Russian Ore Mining Co. LLC with Russian Coal as the operator. The new owner-operator intends to invest in new mining and

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processing equipment with a goal of increasing capacity to 350,000 t/yr. The plans also called for the installation of a 100,000-t/yr briquetting plant to produce metspar briquets, some of which would be intended for Japanese and Korean steel markets (Industrial Minerals, 2005a).

South Africa.—Sallies Ltd. [parent of South African fluorspar producer Witkop Mining (Pty.) Ltd.] announced that it had entered into an agreement (subject to a due diligence review) to purchase Buffalo Fluorspar from Intercoal (Pty.) Ltd. The Buffalo Fluorspar operation is in northern South Africa near Naboomspruit in Limpopo Province east of Sallies' Witkop operation. Sallies planned to raise R47 million by a rights offer to fund the acquisition, pay down existing debt, and finance the expansion of existing operations (Business Day, 2006a§). The Buffalo Fluorspar Mine ceased production in 1994, but recycling operations resumed in 2000 under different owners. A flotation mill was overhauled and recommissioned in 2000, which processed tailings from the previous mining operation. There has been, however, little or no reported output since 2001. The property reportedly still contains recoverable fluorspar in the tailings and large undeveloped reserves of low-grade fluorspar.

Sallies also announced that it intended to sell 30% of the company to black economic empowerment group African Renaissance Investments (Pty.) Ltd. in order to comply with black empowerment laws and codes passed in recent years. The two parties also entered into a joint-venture agreement (70% for Sallies and 30% for African Renaissance), which included an agreement wherein Sallies will manage and operate the business while assisting in the transfer of skills to historically disadvantaged South Africans [Ernst & Young Sponsors (Pty.) Ltd., 2006§].

Sallies announced that it had canceled its supply contract with Honeywell as a result of a dispute over payments. The 5-year contract, which would have expired at the end of 2006, capped the price Honeywell paid at $116 per ton (excluding insurance and freight costs). In the past, Honeywell had consumed as much as 60% of Sallies' annual production. Almost all Sallies' fluorspar is exported in dollar-denominated prices, which made the contract unprofitable to Sallies because of the significant appreciation of the rand against the dollar in recent years. After obtaining legal advice, Sallies canceled the contract in November (Business Day, 2006b§).

A consortium that included the Government and private, local, and international investors was conducting a feasibility study on the construction of a 30,000- to 50,000-t/yr HF and AlF_3 plant. Completion of the study was expected in mid-2006. About 60% of the plant's production would be consumed by South African industries producing aluminum, stainless steel, and petrochemicals. In addition, the HF could be feedstock for future South African refrigeration and fluorochemical industries. Exports would account for 40% of production as AlF_3, HF, or downstream fluorochemicals. With large fluorspar reserves, South Africa could easily expand mine capacity to supply such a plant and maintain current export levels (Venter, 2005§).

Vietnam.—On behalf of Nui Phao Mining Joint Venture Co. Ltd., Tiberon Minerals Ltd. announced that it had been granted a mining license by the Vietnamese Government to develop and mine the Nui Phao tungsten-fluorspar deposit. The license is valid for 30 years and covers about 0.9 square kilometer, which includes the proven and probable reserves located from past exploration drilling (Tiberon Minerals Ltd., 2005b§).

On July 12, Tiberon announced the completion of the "final" feasibility study for the Nui Phao tungsten-fluorspar project. The study concluded that the project could successfully produce more than 210,000 t/yr of fluorspar, about 4,700 t/yr of tungsten, and quantities of bismuth, copper, and gold from an open-pit mining operation with a mine life of 16.3 years. Total capital costs were calculated to be $229.8 million, and based on conservative prices for fluorspar and tungsten (which would account for 80% of the revenue stream), the project's internal rate of return was calculated to be 23.6%. Completion of this final feasibility study allows the company to proceed with project financing, construction, commissioning, and startup of the Nui Phao Mine (Tiberon Minerals Ltd., 2005a§).

Outlook

Demand for acid-grade fluorspar is expected to remain strong in North America because of growing demand for fluorocarbon-base refrigerants. The continued growth in the fluoropolymer and fluoroelastomers markets also will contribute to strong demand. With HF producers DuPont and Honeywell operating their plants at high-capacity rates, supplies of fluorspar will continue to be supplemented by large amounts of imported HF.

With China further restricting exports and export license fees at $56 per ton or more, prices for Chinese acidspar are expected to remain high. Export prices for acidspar will remain high for other major exporting countries, such as Mexico, Mongolia, and South Africa, although significantly lower than the Chinese prices. Despite some recent production capacity increases by non-Chinese producers, there is still insufficient capacity to replace the supplies from China, so consumers will be forced to pay the higher Chinese prices. The closure of Sogerem's fluorspar mines in France reduces world supply by about 100,000 t/yr, which increases the world's dependency on Chinese fluorspar. Additional fluorspar supplies are expected in the next few years from capacity increases in Mongolia (although infrastructure problems make exporting to the West difficult) and possibly South Africa and from the startup of the Nui Phao Mine in Vietnam. But as long as China maintains its export license system on fluorspar, there is likely to be a two-tier pricing system where the price of Chinese acidspar is roughly $30 to $50 per ton higher than that of other exporters on an f.o.b. basis.

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TABLE 1

SALIENT FLUORSPAR STATISTICS[1, 2]

		2001	2002	2003	2004	2005
United States:						
Exports:[3]						
Quantity	metric tons	21,200	24,300	30,700	20,600	36,100
Value[4]	thousands	$3,250	$3,540	$4,610	$3,200	$7,840
Imports:[3]						
Quantity	metric tons	522,000	494,000	567,000	599,000	629,000
Value[5]	thousands	$69,000	$62,000	$76,300	$95,300	$122,000
Average value:[5]						
Acid grade	dollars per metric ton	135	128	138	167	202
Metallurgical grade	do.	80	89	85	83 r	93
Consumption:						
Reported	metric tons	536,000	588,000	616,000	618,000 r	582,000
Apparent	do.	543,000 [6]	477,000 [6]	589,000 [7]	691,000 [7]	616,000 [7]
Stocks, December 31:						
Consumer and distributor[8]	do.	221,000	245,000	206,000	105,000	131,000
Government stockpile	do.	112,000	109,000	95,000	83,400	35,200
World, production	do.	4,600,000 r	4,430,000 r	4,910,000 r	5,220,000 r	5,260,000 e

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits.

[2]Does not include fluorosilicic acid production or imports of hydrofluoric acid and cryolite.

[3]Source: U.S. Census Bureau; may be adjusted by the U.S. Geological Survey.

[4]Free alongside ship values at U.S. ports.

[5]Cost, insurance, and freight values at U.S. ports.

[6]Imports minus exports plus adjustments for Government and industry stock changes.

[7]Imports minus exports plus adjustments for changes in stocks held by Government and three leading consumers.

[8]Includes fluorspar purchased from the National Defense Stockpile (NDS) but still located at NDS depots.

TABLE 2

U.S. REPORTED CONSUMPTION OF FLUORSPAR, BY END USE[1]

(Metric tons)

	Containing more than 97% calcium fluoride		Containing not more than 97% calcium fluoride		Total	
End use or product	2004	2005	2004	2005	2004	2005
Hydrofluoric acid and aluminum fluoride	532,000 r	508,000	--	--	532,000 r	508,000
Metallurgical	20,400	19,600	39,400	29,000	59,700	48,600
Other[2]	26,400	24,900	--	--	26,400	24,900
Total	579,000 r	553,000	39,400	29,000	618,000 r	582,000
Stocks, consumer, December 31[3]	59,500	69,600	15,700	11,200	75,200	80,800

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes acid grade used in enamel, glass and fiberglass, steel castings, and welding rod coatings.

[3]Stocks are from hydrofluoric acid and aluminum fluoride producers and major distributors.

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TABLE 3
PRICES OF IMPORTED FLUORSPAR

(Dollars per metric ton)

Source and grade	2004	2005
Chinese, dry basis, cost, insurance, and freight (c.i.f.) Gulf port, acidspar filtercake	195-205	230-240
Mexican, free on board (f.o.b.) Tampico, acidspar filtercake	168-178	130-150
Mexican, f.o.b. U.S. Gulf port, arsenic <5 parts per million	180-190	175-186
Mexican, c.i.f. port of U.S. entry, metspar[1]	83	93
South African, f.o.b. Durban, acidspar	128-145	157-167

[1]Metspar prices are the average value per metric ton of imported Mexican metspar for the fourth quarter calculated from the U.S. Census Bureau statistics.

Sources: Industrial Minerals, no. 447, December 2004, p. 72; no. 459, December 2005, p. 70.

TABLE 4
U.S. EXPORTS OF FLUORSPAR, BY COUNTRY[1]

	2004		2005	
Country	Quantity (metric tons)	Value[2]	Quantity (metric tons)	Value[2]
Canada	13,700	$2,100,000	28,300	$6,580,000
China	713	127,000	232	38,500
Denmark	11	3,200	--	--
Dominican Republic	308	52,400	758	138,000
Germany	--	--	1	5,000
Japan	37	10,800	--	--
Korea, Republic of	28	4,040	9	9,140
Netherlands	86	12,000	--	--
Taiwan	5,550	834,000	6,680	1,040,000
Venezuela	239 r	55,800 r	120	30,200
Total	20,600	3,200,000	36,100	7,840,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship values at U.S. ports.

Source: U.S. Census Bureau.

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TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF FLUORSPAR, BY COUNTRY AND CUSTOMS DISTRICT[1]

Country and customs district	2004 Quantity (metric tons)	2004 Value[2] (thousands)	2005 Quantity (metric tons)	2005 Value[2] (thousands)
Containing more than 97% calcium fluoride (CaF_2):				
China:				
Houston, TX	151,000	$28,800	229,000	$48,600
Laredo, TX	--	--	2,670	601
New Orleans, LA	179,000	30,300	188,000	39,900
Total	330,000	59,200	420,000	89,200
France, Philadelphia, PA	66	24	39	21
Germany, Savannah, GA	19	9	19	9
Japan, Los Angeles, CA	--	--	1	5
Mexico:				
Houston, TX	16,000	2,920	--	--
Laredo, TX	31,000	5,110	40,000	7,060
New Orleans, LA	32,400	4,060	6,540	730
Total	79,300	12,100	46,500	7,790
Mongolia:				
Houston, TX	10,800	1,570	22,400	4,050
New Orleans, LA	38,300	6,120	20,200	3,200
Total	49,200	7,690	42,600	7,250
South Africa:				
Houston, TX	23,500	3,080	15,000	3,270
New Orleans, LA	64,000	8,830	62,000	10,800
Total	87,400	11,900	77,000	14,100
United Kingdom:				
Houston, TX	1	4	2	8
Los Angeles, CA	507	60	147	18
New York, NY	12	18	--	--
Total	520	82	149	26
Grand total	546,000	91,000	586,000	118,000
Containing not more than 97% CaF_2:				
Canada, Buffalo, NY	13	5	75	29
Mexico:				
Laredo, TX	1,100	120	931	99
New Orleans, LA	50,000	4,100	42,500	3,920
Total	51,100	4,220	43,400	4,020
Venezuela, Virgin Islands	1,880	102	--	--
Grand total	53,000	4,330	43,500	4,050
Grand total, all grades	599,000	95,300	629,000	122,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Cost, insurance, and freight values at U.S. ports.

Source: U.S. Census Bureau; may be adjusted by the U.S. Geological Survey.

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TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF HYDROFLUORIC ACID, BY COUNTRY[1]

	2004		2005	
Country	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Canada	45,500	$48,700	44,100	$46,100
China	950	661	895	599
Germany	261	540	355	704
India	37	33	84	75
Italy	38	58	188	28
Japan	1,370	3,310	1,300	3,100
Korea, Republic of	123	416	172	582
Mexico	79,500	76,200	89,900	86,700
Netherlands	58	245	85	310
Singapore	65	143	32	62
Spain	15	20	--	--
Switzerland	18	80	1	17
Taiwan	58	127	78	110
United Kingdom	-- r	-- r	--	--
Other	-- r	-- r	--	--
Total	128,000	131,000	137,000	138,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Cost, insurance, and freight values at U.S. ports.

Source: U.S. Census Bureau; adjusted by the U.S. Geological Survey.

TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF CRYOLITE, BY COUNTRY[1]

	2004		2005	
Country	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Australia	72	$58	--	--
Belgium	18	16	150	$137
China	647	529	735	576
Denmark	323	525	99	189
Germany	1,970	1,820	1,570	1,720
Hong Kong	382	256	30	18
Hungary	294	293	379	380
United Kingdom	126	119	119	215
Other[3]	32 r	43 r	24	26
Total	3,860	3,660	3,110	3,260

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Cost, insurance, and freight values at U.S. ports.

[3]Includes France, Japan, Spain, and Turkey.

Source: U.S. Census Bureau.

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TABLE 8

U.S. IMPORTS FOR CONSUMPTION OF ALUMINUM FLUORIDE, BY COUNTRY[1]

Country	2004 Quantity (metric tons)	2004 Value[2] (thousands)	2005 Quantity (metric tons)	2005 Value[2] (thousands)
Canada	1,660	$1,500	2,240	$2,340
China	15	36	169	120
Italy	--	--	6	18
Mexico	2,950	2,060	1,660	1,500
Other[3]	75 r	149 r	180	187
Total	4,700	3,750	4,250	4,170

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Cost, insurance, and freight values at U.S. ports.

[3]Includes Japan, and the United Kingdom.

Source: U.S. Census Bureau.

TABLE 9

FLUORSPAR: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country and grade[3, 4]	2001	2002	2003	2004	2005e
Argentina	9,075	5,168	5,422 r	6,891 r	6,200
Brazil, marketable:					
Acid grade	31,263	32,774	34,462 r	40,948 r	45,000
Metallurgical grade	12,471	15,125	21,884 r	16,824 r	18,000
Total	43,734	47,899	56,346 r	57,772 r	63,000
China:e					
Acid grade	1,250,000	1,250,000	1,300,000	1,300,000	1,300,000
Metallurgical grade[5]	1,200,000	1,200,000	1,350,000	1,400,000	1,400,000
Total	2,450,000	2,450,000	2,650,000	2,700,000	2,700,000
Egypte	500	500	500	500	500
France:e					
Acid and ceramic grades	90,000	90,000	79,000	80,000	80,000
Metallurgical grade	20,000	15,000	10,000	10,000	10,000
Total	110,000	105,000	89,000	90,000	90,000
Germanye					
Acid grade	29,400	33,400	32,300	32,200 r	32,200
Metallurgical grade	1,000	1,000	1,000	1,000	1,000
Total	30,400	34,400	33,300	33,200 r	33,200
India:[6]					
Acid grade	6,900	4,188 r	4,200 e	4,300 e	4,400
Metallurgical grade	13,866	6,296	6,300 e	6,400 e	6,500
Total	20,766	10,484 r	10,500 e	10,700 e	10,900
Iran[7]	58,486 r	32,006	47,730 r	54,052 r	54,000
Italy:e					
Acid grade	30,000	30,000	30,000	30,000	30,000
Metallurgical grade	15,000	15,000	15,000	15,000	15,000
Total	45,000	45,000	45,000	45,000	45,000

See footnotes at end of table.

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TABLE 9—Continued
FLUORSPAR: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country and grade[3, 4]	2001	2002	2003	2004	2005[e]
Kenya, acid grade	118,850	85,015	95,278	108,000 [e]	97,261 [8]
Korea, North, metallurgical grade[e]	12,000 [r]	12,000 [r]	12,000 [r]	12,000 [r]	12,500
Kyrgyzstan	1,175	2,750 [e]	3,973	4,000 [e]	4,000
Mexico:[9]					
Acid grade	343,486	343,332	409,122	401,753 [r]	436,000
Metallurgical grade	275,982	279,145	347,136	440,945 [r]	437,000
Total	619,468	622,477	756,258	842,698 [r]	873,000
Mongolia:					
Acid grade	127,000	86,000	120,000 [e]	148,200 [r]	134,100 [8]
Other grades[10]	72,000	99,000	155,000 [e]	206,700 [r]	233,400 [8]
Total	199,000	185,000	275,000 [e]	354,900 [r]	367,500 [8]
Morocco, acid grade	96,500	94,911	81,225	112,100 [r, p]	95,000
Namibia, acid grade[11]	81,551 [r]	81,084	79,349 [r]	104,785 [r]	115,886 [8]
Pakistan, metallurgical grade[e]	1,000	1,000	1,000	1,000	1,500
Romania, metallurgical grade[e]	15,000	15,000	15,000	15,000	15,000
Russia	200,000	169,000	170,000 [e]	200,000 [r]	210,000
South Africa:[12]					
Acid grade	272,068 [r]	216,000 [r, e]	221,000	250,000 [r, e]	252,000
Metallurgical grade	14,319 [r]	11,000 [r, e]	14,000	15,000 [e]	13,000
Total	286,387 [r]	227,000 [r, e]	235,000	265,000 [r, e]	265,000
Spain:					
Acid grade	126,535	131,155	129,195	130,000 [e]	130,000
Metallurgical grade	7,504	10,279	10,503	10,000 [e]	10,000
Total	134,039	141,434	139,698	140,000 [e]	140,000
Tajikistan[e]	9,000	9,000	9,000	9,000	9,000
Thailand, metallurgical grade	3,020	2,271	40,180 [r]	2,375	295 [8]
Turkey, metallurgical grade	4,093	5,344	718	880 [r]	800
United Kingdom[e]	50,000	45,000	60,000	50,000	50,000
Grand total	4,600,000 [r]	4,430,000 [r]	4,910,000 [r]	5,220,000 [r]	5,260,000

[e]Estimated. [p]Preliminary. [r]Revised.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 6, 2005.

[3]In addition to the countries listed, Bulgaria is believed to have produced fluorspar in the past, but production is not officially reported, and available information is inadequate for the formulation of reliable estimates of output levels.

[4]An effort has been made to subdivide production of all countries by grade (acid, ceramic, and metallurgical). Where this information is not available in official reports of the subject country, the data have been entered without qualifying notes.

[5]Includes submetallurgical-grade fluorspar used primarily in cement that may account for 33% to 50% of the quantity.

[6]Year beginning April 1 of that stated.

[7]Year beginning March 21 of that stated. Data for 2001-2004 are reported by Iranian Mines and Mining Development and Renovation Organization.

[8]Reported figure.

[9]Data are reported by Consejo de Recursos Minerales, but the production of metallurgical and acid grades has been redistributed on the basis of industry data.

[10]Principally submetallurgical-grade material.

[11]Data are in wet tons.

[12]Based on data from the South African Minerals Bureau; data show estimated proportions of acid-, ceramic-, and metallurgical-grade fluorpsar within reported totals.

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GALLIUM

By Deborah A. Kramer

Domestic survey data and tables were prepared by Joseph M. Krisanda, statistical assistant.

Gallium metal and gallium arsenide (GaAs) wafer imports continued to supply most of the U.S. gallium demand. Metal imports were 19% lower than those in 2004, with Hungary, Japan, Russia, and Ukraine as the principal import sources. Undoped GaAs wafer imports were 22% higher than those in 2004; China and Germany were the principal sources. Almost all the gallium consumed in the United States was in the form of GaAs and gallium nitride (GaN) and was used in integrated circuits (ICs) and optoelectronic devices [laser diodes, light-emitting diodes (LEDs), photodetectors, and solar cells]. Gallium consumption fell by about 13% from that in 2004, reflecting the continuing shift of device manufacturing from the United States to other countries.

In 2005, estimated world crude gallium production was 70 metric tons (t), about the same as that in 2004. Principal producers were China, Germany, Japan, and Ukraine. Plants in Hungary, Kazakhstan, Russia, and Slovakia also recovered gallium. Refined gallium production was estimated to be about 97 t, which included some new scrap refining. Refined gallium was produced in France, Japan, and the United States.

Legislation and Government Programs

On August 8, the President signed the Energy Policy Act of 2005 (Public Law 109-58). Title IX (Research and Development) of the Act directed the Secretary of Energy to carry out a Next Generation Lighting Initiative (NGLI) to support research, development, demonstration, and commercial application activities for solid-state lighting. The Energy Policy Act authorizes $50 million to the NGLI for each of the fiscal years 2007 through 2009, with extended authorization to allocate $50 million for each of the fiscal years 2010 to 2013 (U.S. Department of Energy, 2005§[1]). Many of the projects funded under NGLI are aimed at improving GaN technology and GaN-base LED performance.

TriQuint Semiconductor Inc. is the prime contractor in a $15.8 million military-funded project to develop GaN-base, high-power, wide-band amplifiers and packaging technology. The project, which is funded by the Defense Advanced Research Projects Agency (DARPA), also includes BAE Systems Inc., EMCORE Corp., II-VI Corp., Lockheed Martin Corp., and Nitronex Corp. If the development is successful, then GaN high-electron-mobility transistors could be used in high-power phased array radar systems, electronic warfare, and communications links. In addition, the DARPA awarded Northrop Grumman Corp. an initial $16.5 million to transition GaN microelectronics from development to production. The aim of this initiative is to develop GaN components for military communications, radar, and intelligence applications. Northrop Grumman began developing GaN technology in 2002 under a $5.1 million phase I contract with the DARPA (Hatcher, 2005).

Production

No domestic production of primary gallium was reported in 2005 (table 1). Recapture Metals Inc. in Blanding, UT, recovered gallium from scrap materials, predominantly those generated during the production of GaAs. Recapture Metals' facilities have the capability to produce about 40 metric tons per year (t/yr) of high-purity gallium. The company recovered gallium from its customers' scrap on a fee basis and purchased scrap and low-purity gallium for processing into high-purity material.

Metallurgical studies by ChelaTech Inc. reported recoveries of greater than 90% of the contained gallium from mineralized rock at Gold Canyon Resources Inc.'s Cordero gallium project in Humboldt County, NV. Actual recovery ranged from 91.6% to 96.8% of the total gallium contained in mineralization at Cordero. The process developed to recover gallium was a multistep acid leach process using commonly available acids and reagents, which is similar to the acid leach process used to treat copper oxide ores (Gold Canyon Resources Inc., 2005§).

Consumption

Gallium consumption data were collected by the U.S. Geological Survey from a voluntary survey of U.S. operations. In 2005, there were eight responses to the consumption of gallium survey, representing 38% of the total canvassed. Data in tables 2 and 3 were adjusted by incorporating estimates to reflect full industry coverage. Many of these estimates were based on the companies' 2005 10-K reports submitted to the Securities and Exchange Commission.

More than 95% of the gallium consumed in the United States was in the form of GaAs or GaN. GaAs was used to manufacture optoelectronic devices (laser diodes, LEDs, photodetectors, and solar cells) and ICs. ICs accounted for 63% of domestic consumption, optoelectronic devices accounted for 22%, and 15% was used in research and development and other applications (table 2). GaN principally was manufactured into LEDs and laser diodes.

Gallium Arsenide.—In January, RF Micro Devices Inc. (RFMD) and the United Kingdom's Filtronic plc signed a supply agreement whereby Filtronic will become RFMD's leading supplier of GaAs-base pseudomorphic high-electron-mobility transistors (pHEMTs). Filtronic will manufacture the components at its 6-inch wafer processing facility in Newton Aycliffe, United Kingdom. The pHEMTs will be incorporated into RFMD modules for cell phone handset and wireless local area network (LAN) applications (Compound Semiconductor, 2005e). As a result of the contract, Filtronic increased the

[1]References that include a section mark (§) are found in the Internet References Cited section.

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operating rate at its United Kingdom facility to 24 hours per day, 7 days per week.

In April, EMCORE announced plans to close its solar panel operations in City of Industry, CA, and consolidate into a facility in Albuquerque, NM. In August, however, EMCORE received an $8.0 million contract for solar panels for a new communications satellite. This contract also contained options for several additional sets of solar panels with deliveries through early 2007. As a result of this award and an accelerated delivery schedule, EMCORE decided to keep its California facility open until contract deliveries were completed. Production at the facility was expected to be discontinued during 2006 and the plant to be completely closed by March 2007 (Compound Semiconductor, 2005b).

Sumika Electronic Materials Inc. added GaAs pHEMT epitaxial wafer manufacturing capability at its Phoenix, AZ, facility. The company (owned by Japan's Sumitomo Chemical Co. Ltd.) already makes GaAs heterojunction bipolar transistor (HBT) epitaxial wafers in Phoenix. The addition of two new metal-oxide chemical vapor deposition (MOCVD) systems means that Sumika now has two production sites for both pHEMT and HBT epitaxial wafers—the other is in Chiba, Japan (Compound Semiconductor, 2005l).

Koninklijke Philips Electronics N.V. announced that it would buy Agilent Technologies Inc.'s 47% share in LED manufacturer Lumileds Lighting for $948 million in cash. The deal, which would give Philips 96.5% ownership of Lumileds, was part of Aglient's plan to sell off its entire semiconductor business unit, which also included GaAs IC, fiber-optic component, and low-brightness LED manufacturing facilities. Lumileds was Hewlett-Packard Co.'s optoelectronics division, and that division became part of Agilent Technologies when Hewlett-Packard split into two businesses in 1999 (Compound Semiconductor, 2005i). In December, private equity firms Kohlberg Kravis Roberts & Co. and Silver Lake Partners took control of Agilent's remaining semiconductor business in a deal worth about $2.66 billion. These firms renamed the business Avago Technologies Ltd. (LEDs Magazine, 2005a§).

In June, Mimix Broadband Inc., a supplier of microwave and millimeter-wave GaAs semiconductors, acquired the remaining assets of Celeritek Inc. for $2.8 million. The GaAs component operation that Mimix acquired included such products as low-noise amplifiers, gain blocks, and power amplifier modules for both commercial and defense applications. In September 2003, Celeritek had exited the cell phone handset power amplifier business and had decided to concentrate on defense markets. Shortly afterwards, Anadigics Inc. acquired the Tavanza handset power amplifier design business from Celeritek, and in July 2004, Teledyne Technologies Inc. purchased Celeritek's defense electronics business (Compound Semiconductor, 2005h).

In September, Goodrich Corp., a supplier of systems and services to aerospace, defense, and homeland security markets, announced that it would acquire Sensors Unlimited Inc. for $60 million. Sensors Unlimited produced indium gallium arsenide (InGaAs) imaging technology and had in-house manufacturing capabilities for advanced infrared cameras and short-wave infrared and near-infrared focal plane arrays. Sensors Unlimited's products were used in commercial, industrial, military, security, and telecommunications applications, such as covert surveillance, health and safety protocols, historical art inspection, and night vision (Goodrich Corp., 2005§). In September, Sensors Unlimited was awarded a $4.5 million contract from the DARPA to develop an InGaAs focal plane array, which will form the basis of an uncooled dual-wavelength camera that is sensitive between 0.4 and 1.7 micrometers (μm) and capable of night vision imaging. The goal of the focal plane array will be to identify a human target at a distance of 100 meters under no-moon conditions (Compound Semiconductor.net, 2005h§).

In January, Endwave Defense Systems (a wholly owned subsidiary of Endwave Corp.) announced that it was awarded a $518,000 contract with a major U.S. prime defense contractor to design and deliver prototype low-power GaAs-base amplifiers for use in the back-fit of an airborne defense system in the 20-plus-year-old North Atlantic Treaty Organization aircraft fleet. Prototype deliveries were expected to start during the fourth quarter of 2005. Upon successful field qualification testing, production was expected to begin in 2006 and last 2 to 4 years (Compound Semiconductor, 2005d).

U.S. defense contractor Raytheon Corp. won a $580 million contract to produce GaAs-base radars for use in fighter aircraft used by the U.S. Navy. Under the 5-year production contract, Raytheon will deliver 190 active electronically scanned array APG-79 radar systems to Boeing Corp. to be installed on the F-15 Eagle and F/A-18 Super Hornet. The new system also has the potential to be used in unmanned aircraft. The APG-79 system will allow the aircraft to track other aircraft at longer ranges, provide higher resolution synthetic aperture radar maps, and allow near-simultaneous air-to-air and air-to-ground sensing. The first system was delivered to Boeing Integrated Defense Systems in January (Compound Semiconductor, 2005k).

Gallium Nitride.—Picogiga International (a division of the Soitec Group) adapted its silicon-on-insulator technology to produce 2-inch diameter GaN-on-insulator substrates; this represents the first single-crystal GaN-on-insulator substrate. The new technology could lead to improvements in the performance of GaN-base devices, such as blue and white LEDs and high-power microwave components. Picogiga has produced only 2-inch diameter GaN-on-insulator wafers, but says that the technique will be suitable for larger substrates as soon as these become available. However, production quantities of GaN-on-insulator wafers will not be available until bulk GaN substrates become more affordable and widely used, with Picogiga not expecting commercialization until 2006 or 2007 (Compound Semiconductor, 2005f).

In July, Veeco Instruments Inc. and Picogiga announced that they would set up a development program to create the first industrial molecular beam epitaxy (MBE) reactor set up specifically for Picogiga's patented GaN-on-silicon manufacturing process. Once it has been built, Veeco will deliver and install the reactor at Picogiga's Les Ulis production facility in France, where it will be used to fabricate GaN-on-silicon epitaxial wafers of up to 6 inches in diameter (Compound Semiconductor, 2005n).

EMCORE decided to spin off a new company, Velox Semiconductor Corp., to commercialize its fast, high-voltage GaN diodes for high-power electrical supply applications. EMCORE

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holds a 20% stake in Velox, which has raised $6 million from three venture capital partnerships. According to EMCORE, the formation of the new company will reduce operating expenses and allow EMCORE to benefit from the technology with its 20% ownership (Compound Semiconductor, 2005c).

The battle among manufacturers of DVD players to agree on a standard format (high definition or Blu-ray) for the next generation of DVD players, which use GaN-base laser diodes, continued in 2005. Toshiba Corp. reportedly developed a triple-layer version of its high-definition DVD disc that holds up to 45 gigabytes of data. The disc, which would be read by an optical head with a GaN-base blue laser diode, could record 12 hours of high-definition movies. Toshiba also announced that it has a novel disc technology that would allow consumers to view standard DVD content using existing players as well as high-definition content with next-generation technology. Matsushita Electric Industrial Co. Ltd. (manufacturer of products under the Panasonic brand name), however, planned to start operating a pilot-production line for Blu-ray disc replication in Torrance, CA, in May, with full production expected to begin in January 2006 (Compound Semiconductor, 2005m). In October, Toshiba and Matsushita each announced that they would mass-produce drives for desktop and notebook personal computers—Toshiba would manufacture discs with the high-definition format, and Panasonic would use the Blu-ray format. These would be available in early 2006 (Compound Semiconductor, 2005a).

Light-Emitting Diodes.—Many LED manufacturers introduced new LEDs based on GaAs and GaN technology that offer improvements from currently produced LEDs. In many cases, the new LEDs are brighter, last longer, and/or can be used in new applications. These new products have applications that include automotive lighting, cellular telephones, entertainment and decorative lighting, and signage.

According to a new report by Strategies Unlimited (a research unit of PennWell Corp.), more than 100 companies now produce high-brightness (HB) LEDs at various levels of the vertical supply chain. Out of a total of 30 companies selling epitaxial wafers and/or HB-LED chips in 2004, the top 3 suppliers accounted for more than one-half of the sales of these materials. Asia was the dominant supplier, accounting for 76% of the packaged HB-LED market and 57% of epitaxial wafer and chip sales in 2004 (Compound Semiconductor.net, 2005c§).

In February, Kopin Corp. announced that it would form a joint venture company to spin off its indium gallium nitride (InGaN) LED technology to a low-cost manufacturing operation in Asia. As a result, Kopin would stop manufacturing LEDs in the United States and concentrate its efforts on the manufacture of GaAs HBT epitaxial wafers. Taiwan-based Bright LED Electronics Corp. was one of the other partners in the joint venture, which was named KoBrite Corp. In November, the joint venture's production facility in Dongguan, China, opened, although the epitaxial growth stage in the chip fabrication process will take place in Taiwan (Compound Semiconductor.net, 2005f§).

Light Waves Concept Inc. (a New York, NY-based LED product manufacturer) was working with the U.S. Department of Defense on an evacuation system using LED technology. The system is made up of LED rope lights that line hallways within buildings and are connected to a controller. In the event of an emergency, the controllers will illuminate the ropes in a series of different flashing patterns and colors. The colors used will be those of a traffic light and will send the same signals to the evacuees—red for stop, green for go, and yellow for move cautiously. Biochemical, motion, and temperature sensors will feed data to the controllers based on the nature and severity of the emergency. The project is a new use for LED rope lights, which have been used mainly to highlight signage boards and buildings (LEDs Magazine, 2005g§).

III-N Technology Inc., a spin-off from Kansas State University, developed single-chip power LED lamps that can be plugged directly into standard power outlets or lamp sockets without power conversion. Normally, standard power LEDs operate from a direct current (DC) supply with a voltage of around 3.5 volts (V) (for blue devices); the new chips are capable of operating directly from an alternating current (AC) supply with a voltage of 110 V or 220 V. The new technology eliminates the need for an AC-DC power converter, which is expected to lead to significant cost savings. The main advantage, however, is the compatibility with the existing lighting and electricity infrastructure. The company has applied for patent protection covering its invention (LEDs Magazine, 2005j§).

Showa Denko K.K. has developed two new GaN-base LED chips that it planned to produce in large volumes. Showa Denko's proprietary near-ultraviolet and green LED chips were aimed at applications in general lighting and backlighting of large liquid crystal display (LCD) screens. The company had previously commercialized blue LEDs based on similar structures and has the capacity to produce 30 million GaN-base chips per month at its plant in Chiba, Japan (Compound Semiconductor.net, 2005i§).

A U.S. team conducted what is believed to be the first demonstration of a flow-through water purification module that uses ultraviolet LEDs. In collaboration with microbiologists at the University of Maine, Hydro-Photon Inc. developed a bench-level prototype flowing water treatment module that uses 10 aluminum gallium nitride (AlGaN) LEDs made by Sensor Electronic Technology Inc. In tests using sterile tap water contaminated with E. coli at a concentration of 10,000 microbes/milliliter, the ultraviolet LEDs destroyed at least 95.5% of the bacteria. Such purification modules, which would be far smaller and more convenient than those that use mercury lamps to kill bacteria, could become a high-volume market for ultraviolet LEDs in the future. Later in 2005, Hydro-Photon demonstrated water purification at flow rates close to those required for individual water treatment applications by using more powerful LEDs. Hydro-Photon's chamber reduced the level of E coli in water flowing at 150 milliliters per minute (mL/min) and 300 mL/min by 99.99% and 99.0%, respectively. Individual water treatment systems would typically require a flow rate of 500 mL/min (Compound Semiconductor.net, 2005a§). Sensor Electronic Technology also supplied LEDs to a firm that has built a prototype to treat raw sewage. Ohio-based start-up company Oh! Technology LLC (OHT) claimed to have reduced bacteria levels in flowing raw sewage by 60% using ultraviolet LEDs. OHT's first battery of tests, which began in February, analyzed the effect of a prototype module containing 16 AlGaN LEDs on raw fecal sewage at a local wastewater treatment facility (Compound Semiconductor, 2005g).

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Permlight Products Inc. incorporated LEDs from Osram Opto Semiconductors GmbH into a new system that prevents the use of digital camcorders in cinemas. Permlight's line of antipiracy products uses Osram's recently introduced thin-film infrared power LED technology to transmit a harmless signal that is invisible to humans. The signal is directed towards movie audiences in cinema theaters and will wash out digital camcorders, preventing signals from being recorded. The system sells for between $1,200 and $5,000, depending on the size of the movie screen (LEDs Magazine, 2005i§).

The Diamond Vision LED screen, which was installed during a renovation of Turner Field in Atlanta, GA, is said to be the world's largest outdoor high-definition display. The 520-square-meter (m^2) (5,600-square-foot) Mitsubishi Electric Diamond Vision screen, which was recognized by Guinness World Records, is 21.6 meters (m) tall and 24.1 m wide and weighs 45 t. It consists of 266 panels that contain 20 lighting units each, resulting in a screen with almost 5.2 million LED modules that can reproduce 1 billion colors and be clearly seen from almost any viewing angle. Diamond Vision is a division of Mitsubishi Electric Power Products Inc. (a U.S. subsidiary of Mitsubishi Electric Corp. of Japan) (LEDs Magazine, 2005e§).

Prices

Since 2002, producer prices for gallium have not been quoted in trade journals. Data in table 4 represent the average customs value of gallium imported into the United States. Reports in Mining Journal indicated that gallium prices rose slightly during 2005. At the beginning of the year, low-grade gallium prices were reported to be about $300 per kilogram. By April, the price increased to $330 to $350 per kilogram and then increased to about $400 per kilogram in June. By yearend, the price had decreased to $330 to $380 per kilogram. Metal-Pages reported similar price movements for the low-purity material. For high-purity gallium, Metal-Pages reported that prices early in 2006 were about $400 per kilogram, but increased to $617 per kilogram by midyear.

From U.S. Census Bureau import data, the annual average value for low-grade gallium was estimated to be $244 per kilogram, almost 30% higher than the revised average value in 2004. For high-grade gallium, the annual average estimated value fell to $538 per kilogram from a revised figure of $550 per kilogram. Import data, reported by the U.S. Census Bureau, do not specify purity, so the values listed in table 4 are estimated based on the average value of the material imported and the country of origin.

Foreign Trade

In 2005, U.S. gallium imports were 19% lower than those in 2004 (table 5). Japan (27%), Russia (16%), Hungary (13%), and Ukraine (13%) were the leading sources of imported gallium. U.S. consumption of gallium metal has diminished mainly because a significant portion of the GaAs manufacturing capacity has moved to other countries, such as China and Taiwan. Gallium metal imports, therefore, are not expected to be as large as they have been in the past several years.

In addition to gallium metal, GaAs wafers were imported into the United States (table 6). In 2005, 4,350 kilograms (kg) of undoped GaAs wafers and 200,000 kg of doped GaAs wafers were imported. The data listed in table 6 may include some packaging material and, as a result, may be higher than the actual total weight of imported wafers.

World Review

Imports of gallium into Japan and the United States, the two leading consuming countries, have been used as the basis for estimating world gallium production. Estimated crude gallium production was 70 t in 2005. Principal world producers were China, Germany, Japan, and Ukraine. Gallium also was recovered in Hungary, Kazakhstan, Russia, and Slovakia. Refined gallium production was estimated to be about 97 t; this included some new scrap refining. France was the leading producer of refined gallium using gallium produced in Germany as feed material. Japan and the United States also refined gallium. Gallium was recycled from new scrap in Germany, Japan, the United Kingdom, and the United States.

China.—A newly discovered coal deposit in China's Inner Mongolia Autonomous Region was reported to contain 875,000 t of gallium (Metal-Pages, 2005a§).

Germany.—Jenoptik Diode Lab GmbH planned to increase production of its GaAs laser diode chips in early 2006. The small company, which was set up in 2002 as a spinoff of the Ferdinand Braun Institute for High Frequency Technology, will build a new facility in Berlin-Adlershof to manufacture the chips. The complex will include 500 m^2 of clean rooms for 3-inch GaAs production, as well as in-house research and development laboratories and offices. Diode Lab principally will be manufacturing lasers for its parent company Jenoptik Laserdiode GmbH, with the lasers destined for applications in materials processing, medicine, and displays (Compound Semiconductor.net, 2005d§)

Japan.—In 2005, Japan's virgin gallium production was estimated to be 9 t, gallium recovered from scrap was reported to be 83 t, and gallium imports were reported to be 45 t, for a total supply of 136 t. China (29%), Taiwan (17%), and the United States (20%) were estimated to be the principal sources of gallium imported into Japan (Roskill's Letters from Japan, 2005).

Kazakhstan.—Production of gallium in Kazakhstan in 2005 was reported to be 6,245 kg (Metal-Pages, 2006§).

Russia.—In October, Fosagro AG announced that it would construct two nepheline concentrate processing plants—one at Kirov and the other at Murmansk—at a cost of $1 billion each. In conjunction with the new facilities, Fosagro planned to install 30 t of gallium recovery capacity at each plant. The first plant was scheduled to be completed within 3 to 4 years (Metal-Pages, 2005b§).

Taiwan.—The LED production industry continued to consolidate in 2005. In August, Epistar Corp. announced that it would acquire United Epitaxy Co. Ltd. through a share swap to create the nation's leading LED manufacturer. The new company will retain the Epistar name and will combine two complementary technologies—Epistar's high-luminance blue LEDs, and United Epitaxy's AlGaInP LEDs (Taiwan's leading supplier). In

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February, South Epitaxy Corp., which supplies LED epitaxial wafers and chips, announced that it would acquire Epitech Technology Corp. through a share-swap transaction (Taipei Times, 2005§). A review of Taiwan's gallium manufacturing industry was published in January (III-Vs Review, 2005§).

Everlight Electronics Co. Ltd. planned to invest $14.9 million in an LED production capacity expansion in 2006. The expansion will increase Everlight's total monthly LED capacity to 650 million units from 372 million units by the end of 2006. Most of Everlight's LEDs are used in handset applications, while future growth will be driven by the automotive market and by the adoption of white LEDs as backlights for small LCD panels (LEDs Magazine, 2005b§).

Ukraine.—Rusal Ltd. announced that it would increase gallium production capacity at its Nikolaev Alumina Refinery to 12 t in 2006 from 10.5 t in 2005. Gallium production at the plant has been increasing steadily since 2003. In 2003, the plant produced 4 t of gallium, and in 2004, 10 t (Metals and Mining Weekly, 2005).

Current Research and Technology

In September, Princeton Lightwave Inc. (PLI) introduced a new InGaAs-indium phosphide (InP) single photon avalanche diode that it claimed to be the first commercially available device designed and optimized specifically for applications where extremely low light levels require the capability to detect single photons. These applications include quantum information processing, long-range light detection and ranging (LIDAR), long-range terrestrial and satellite free-space communications, scientific instrumentation, and quantum cryptography for secure communications. Early in 2006, PLI planned to introduce products for quantum cryptography applications that use these avalanche photodetectors combined with technology licensed from IBM Corp. By combining the two technologies, PLI believes that it can become the first commercial supplier of single-photon detectors for quantum cryptography systems. Invented in 1984, quantum cryptography takes advantage of the quantum physics of light. In theory, it allows two users to communicate securely over a normally insecure channel, such as a regular optical fiber (Compound Semiconductor, 2005j).

Toshiba developed a fluorescent converter material that allows white LEDs to produce light that is close in appearance to sunlight. The newly developed material transforms blue LED light into various colors ranging from blue to yellow and orange and is designed to be used in combination with an additional fluorescent material that converts blue to red. Conventional white LEDs use a fluorescent material that converts blue to yellow, resulting in artificial white light containing no green or orange. As a result, red and green objects appear dark with poor color rendering. Products containing the material could be available in 2 or 3 years (LEDs Magazine, 2005h§).

Scientists at the Lighting Research Center at Rensselaer Polytechnic Institute have developed a method to get significantly more light from white LEDs without requiring more energy. Commercially available white LEDs combine a light-emitting semiconductor with a phosphor to produce visible white light. However, more than one-half of the light produced by the phosphor is diverted back toward the LED where much of it is lost because of absorption, which reduces the LED's overall light output. The scientists developed a method to extract the backscattered photons by moving the phosphor away from the semiconductor and reshaping the LED lens geometry. The researchers claim that compared to commercial white LEDs, prototypes of the new LED technology produced 30% to 60% more light output and lumens per watt of electricity. The research was funded by the U.S. Department of Energy's Building Technologies Program (Rensselaer Polytechnic Institute, 2005§).

In a different method to produce more efficient LEDs, a team of scientists at Los Alamos National Laboratory and Sandia National Laboratory developed the first completely inorganic, multicolor LED based on colloidal quantum dots encapsulated in a GaN semiconductor. The devices, which have cadmium selenide nanocrystals incorporated within a GaN-base light-emitting region, circumvent the inefficiencies of using phosphors to convert blue emission into yellow light, which include losses associated with light capture of the phosphor, nonradiative carrier losses during the reemission process, and losses because of reabsorption of the color-converted photons by the phosphor. Standard GaN deposition methods could not be used because the high temperatures would have degraded the nanocrystals. Instead, the researchers used a new lower temperature technique, which they call energetic neutral atom beam lithography/epitaxy (ENABLE). With this, they created films said to be as good as those produced by MOCVD (Compound Semiconductor.net, 2005j§).

Two additional groups of scientists were trying to increase the efficiency of white LEDs by capturing the light that is lost. Researchers from Meijo University, Japan, claimed that they have doubled the efficiency of white LEDs. Instead of using blue-emitting devices and color-converting yellow phosphors, the researchers use a purple-emitting LED combined with a "structured" silicon carbide (SiC) substrate that converts this emission into white light. The Japanese researchers have submitted patent applications for the structure of the SiC substrate (Compound Semiconductor.net, 2005e§). Scientists at Seoul National University, Republic of Korea, reportedly have more than doubled the output power of blue GaN-base LEDs with a holographic process that etches a two-dimensional photonic crystal into the device (Compound Semiconductor.net, 2005g§).

Research groups at the University of California at Santa Barbara, the University of Tsukuba [Japan], and the Tokyo University of Science [Japan] reportedly developed a new class of GaN semiconductor thin films, which are used to make blue and green LED chips. The new materials are known as semipolar and nonpolar GaN. The researchers demonstrated that the optical output power of LEDs fabricated using nonpolar and semipolar GaN saturates at much higher drive currents than for conventional LEDs, which is promising for high-brightness applications, such as automobile headlights. Semipolar and nonpolar GaN films have a different crystal structure from conventional GaN, with reduced or zero built-in electric fields. This makes it easier for the process leading to light emission to happen (LEDs Magazine, 2005c§).

Collaborators from National Aeronautics and Space Administration's Jet Propulsion Laboratory and IQE plc claim to have produced the world's first four-band infrared camera.

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Based on quantum-well infrared photodetector (QWIP) technology, the camera is suitable for applications including weather prediction and remote sensing of pollution, such as the detection of nitrous oxide in smog. It has already been used as part of an international project investigating the environmental impact of vegetation burning and related ecological effects in Africa. It also has the potential to assist with monitoring crop health, tropical rainforest deforestation, and industrial pollutants. The new QWIP camera can see up to 15.5 μm, and its focal plane can be compared to the retina of an eye. The QWIP camera contains GaAs-base material that was grown at IQE's U.S. facility in Bethlehem, PA (Stevenson, 2005).

Outlook

A report from Strategy Analytics Inc. forecast that 1 billion cell-phone handsets would be shipped worldwide in 2006. If this is correct, then the growth, largely fueled by strong sales from Nokia Group and caused by robust demand in emerging markets like India, would represent a 22% increase compared with the 2005 figure of 817 million shipments. Cell phone manufacturer Nokia, however, predicted an industry growth rate of about 15% in 2006. As phones become more complex, multiple power amplifiers manufactured from GaAs-base components are needed in the handset (Compound Semiconductor.net, 2006§). In response to these forecasts, GaAs manufacturing firms are either bringing idled capacity onstream or are announcing capacity increases. If these forecasts are overoptimistic, however, there could be a repeat of the same situation that happened in 2000-02. Gallium supplies were tight and prices skyrocketed in 2000 as companies increased their GaAs production to meet a predicted high demand for cell phone components. As the economy stagnated, the anticipated cell phone demand did not materialize, leaving cell phone manufacturers with excess inventory. The gallium market remained depressed, prices fell, and GaAs manufacturing firms closed some of their capacity until the excess inventory was sold.

Although the market for power amplifiers in cell phones was expected to increase, two market research firms predicted that the market for HB-LEDs in cell phones would either decrease or grow at a much slower rate than in the past. iSuppli Corp. predicted that the backlighting of LCD displays in mobile phones would start to slow as shipments of wireless handsets begin to decelerate and that many of the new lighting applications for the next generation of ultrahigh-brightness LEDs have not been commercialized yet, which would slow near-term growth (LEDs Magazine, 2005f§). Strategy Analytics expected that the introduction of brighter LEDs and more efficient backlighting schemes would cause a net reduction in the average number of LEDs used in both the LCD and keypad backlighting segments of the market. This loss, however, would be offset by strong growth in the emerging camera flash segment. By 2009, revenues from the growing camera flash function would represent 36% of the total handset LED market demand (LEDs Magazine, 2005d§).

Strategy Analytics also predicted that the global semi-insulating (SI) GaAs substrate market will grow in area by 43% by 2009. Sales of SI GaAs substrates were predicted to rise from 14 million square inches in 2004 to 20 million square inches in 2009, and worldwide SI GaAs revenue was expected to increase by 9% to 10% per year. In general, average selling prices were continuing to decline by at least 5% year-on-year. The decline in the price of 6-inch wafers, however, has slowed, partly because of an increase in the cost of raw gallium. Although by 2003 companies had been expected to switch to 6-inch from 4-inch substrates, sales of 4-inch substrates still accounted for 50% of the total (Compound Semiconductor.net, 2005b§).

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TABLE 1
SALIENT U.S. GALLIUM STATISTICS[1]

(Kilograms unless otherwise specified)

	2001	2002	2003	2004	2005
Production	--	--	--	--	--
Imports for consumption	27,100	13,100	14,300	19,400	15,800
Consumption	27,700	18,600	20,100	21,500	18,700
Price dollars per kilogram	640 [2]	530 [3]	411 [3]	550 [r,3]	538 [3]

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits.

[2]Source: American Metal Market.

[3]Estimate based on average value of U.S. imports of high-purity gallium.

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TABLE 2
U.S. CONSUMPTION OF GALLIUM, BY END USE[1, 2]

(Kilograms)

End use	2004	2005
Optoelectronic devices:		
Laser diodes and light-emitting diodes	6,930	3,880
Photodetectors and solar cells	809	219
Integrated circuits:		
Analog	9,890	11,700
Digital	63	115
Research and development	3,690	2,800
Other	111	76
Total	21,500	18,700

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes gallium metal and gallium compounds.

TABLE 3
STOCKS, RECEIPTS, AND CONSUMPTION OF GALLIUM, BY GRADE[1, 2]

(Kilograms)

Purity	Beginning stocks	Receipts	Consumption	Ending stocks
2004:				
99.99% to 99.999%	340	151	35	456
99.999%	729	5,720	5,330	1,120
99.99999% to 99.999999%	126	608 r	507	137 r
Total	1,200	6,480 r	5,870	1,720 r
2005:				
99.99% to 99.999%	456	59	12	503
99.999%	1,120	3,390	3,350	1,160
99.99999% to 99.999999%	137	139	140	136
Total	1,720	3,590	3,500	1,800

rRevised.

[1]Consumers only.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
ESTIMATED YEAREND GALLIUM PRICES

(Dollars per kilogram)

Gallium metal	2004 r	2005
99.9999%-pure, average value of U.S. imports	550	538
99.99%-pure, average value of U.S. imports	188	244

rRevised.

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TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF GALLIUM (UNWROUGHT, WASTE, AND SCRAP), BY COUNTRY[1]

Country	2004		2005	
	Quantity (kilograms)	Value[2]	Quantity (kilograms)	Value[2]
Canada	763	$151,000	1,090	$269,000
China	4,740	1,050,000	1,530	624,000
France	1,170	569,000	1,520	775,000
Germany	37	15,800	26	22,800
Hungary	2,300	476,000	2,100	535,000
Japan	5,380	828,000	4,290	814,000
Russia	1,740	508,000	2,480	695,000
Ukraine	3,000	420,000	2,000	540,000
United Kingdom	182	46,700	215	103,000
Other	101 r	62,900 r	513	521,000
Total	19,400	4,130,000	15,800	4,900,000

rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Customs value.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF GALLIUM ARSENIDE WAFERS, BY COUNTRY[1]

Country	Undoped				Doped			
	2004		2005		2004		2005	
	Quantity (kilograms)	Value[2]	Quantity (kilograms)	Value[2]	Quantity (kilograms)	Value[2]	Quantity (kilograms)	Value[2]
Canada	2,260	$28,500	--	--	25	$102,000	16	$53,600
China	27	9,380	2,000	$530,000	12,000	19,700,000	8,900	14,000,000
Finland	--	--	--	--	8,750	10,400,000	8,270	13,200,000
Germany	103	4,960	1,200	50,300	31,500	27,600,000	25,400	27,900,000
Japan	111	92,900	7	8,110	80,500	50,800,000	50,900	47,200,000
Korea, Republic of	14	10,200	--	--	64,500	23,800,000	44,500	27,500,000
Russia	502	182,000	498	124,000	88	215,000	391	580,000
Singapore	557	116,000	--	--	257	692,000	3,290	4,860,000
Taiwan	3	14,900	--	--	22,200	12,500,000	17,500	9,470,000
Ukraine	--	--	620	133,000	--	--	3	23,300
United Kingdom	2	17,700	31	4,540	164	451,000	26,800	4,540,000
Other	6	4,590	--	--	6,440	7,300,000	13,600	12,700,000
Total	3,580	481,000	4,350	850,000	226,000	153,000,000	200,000	162,000,000

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Customs value.

Source: U.S. Census Bureau.

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TABLE 7
ESTIMATED WORLD ANNUAL PRIMARY GALLIUM PRODUCTION CAPACITY, DECEMBER 31, 2005[1]

(Metric tons)

Country	Capacity
China	59
Germany	35
Hungary	8
Japan	20
Kazakhstan	20
Russia	19
Slovakia	8
Ukraine	10
Total	179

[1]Includes capacity at operating plants as well as at plants on standby basis.

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GARNET, INDUSTRIAL

By Donald W. Olson

Domestic survey data and table were prepared by Nicholas A. Muniz, statistical assistant.

This report includes information on garnet produced in the United States that was used for industrial purposes. Current information on gem-grade garnet can be found in the U.S. Geological Survey (USGS) Minerals Yearbook, volume I, Metals and Minerals chapter on gemstones. Trade data in this report are from the U.S. Census Bureau. All percentages in the report were computed using the unrounded data.

In 2005, U.S. production of crude garnet concentrate for industrial use was estimated to be 40,100 metric tons (t) valued at about $3.84 million. U.S. imports and exports of industrial garnet were estimated to be 41,800 t and 13,400 t, respectively. U.S. apparent consumption was estimated to be 68,600 t.

Garnet has been used as a gemstone for centuries. Garnet necklaces dating from the Bronze Age have been found in graves, and garnet is found among the ornaments adorning the oldest Egyptian mummies. However, garnet's angular fractures, relatively high hardness and specific gravity, chemical inertness, nontoxicity, lack of crystalline silica, and its ability to be recycled make it ideal for many industrial applications.

Garnet is the general name given to a group of complex silicate minerals, all with isometric crystal structure and similar properties and chemical composition. The general chemical formula for the garnet minerals is $A_3B_2(SiO_4)_3$, where A can be calcium, ferrous iron, magnesium, or manganese, and B can be aluminum, chromium, ferric iron, or rarely, titanium. The most common garnet minerals are classified into three groups—the aluminum-garnet group, the chromium-garnet group, and the iron-garnet group. The most common minerals of the aluminum-garnet group are almandine or almandite, grossularite, pyrope, and spessartite. Andradite is the most common iron-garnet mineral, and uvarovite is the most common chromium garnet. Garnet occurs worldwide in many rock types, principally gneisses and schists; other sources include contact metamorphic rocks, metamorphosed crystalline limestones, pegmatites, and serpentinites. Alluvial garnet is associated with heavy-mineral sand and gravel deposits in many parts of the world. Occurrences of garnet are numerous; however, relatively few commercially viable garnet deposits have been discovered.

Production

The U.S. industrial garnet industry is dominated by a few major producers. The garnet industry has encountered higher production costs and tighter profit margins during recent years. These factors have resulted in the loss of noncompetitive producers. Because of the need to keep production costs at a minimum, the most competitive producers are those who produce garnet in combination with one or two other minerals, have reserves that can be mined at a low cost, and have the ability to react rapidly to changes in market demands. The value of industrial garnet is influenced by the size and grade of reserves, the type and quality of garnet mined, the proximity of deposits to infrastructure and consumers, and the milling costs. Pricing within the U.S. garnet industry is very competitive, and suppliers must provide a high level of customer service. The majority of industrial-grade garnet mined in the United States is almandine (iron aluminum silicate) and pyrope (magnesium aluminum silicate); some andradite (calcium iron silicate) also is mined domestically. Industrial garnet is produced from alluvial bar and beach deposits, like those in Idaho and Montana (also those in Australia and India), and it is produced from hard rock deposits, like those in New York (Moore, 2006).

Four U.S. companies accounted for all domestic production—one in Idaho, one in Montana, and two in New York. The USGS obtained the data in this report through a survey of U.S. industrial garnet producers. Two of the three domestic producers reported their output and sales to the USGS, and production amounts and values for the nonreporting company were estimated.

In 2005, U.S. production of crude garnet concentrate for industrial use was estimated to be 40,100 t valued at about $3.84 million (table 1). This was a 41% increase in production and an increase of about 26% in value compared with 28,400 t valued at $3.05 million in 2004. Refined garnet material sold or used amounted to 23,100 t valued at $6.20 million and a unit value of $268 per ton, a 24% decrease in quantity, a decrease of about 38% in value, and a decrease of almost 19% in unit value compared with the 2004 levels. The producers were Barton Mines Co. LLC in Warren County, NY; Emerald Creek Garnet Co. in Benewah County, ID; NYCO Minerals, Inc. in Essex County, NY; and Ruby Valley Garnet LLC in Madison County, MT. In addition to the producers cited above, International Garnet Abrasive Inc. in Clinton County, NY, processed and sold all the garnet mined by NYCO Minerals in 2005.

Consumption

The United States continued to be one of the world's leading consumers of industrial garnet. In 2005, the estimated U.S. apparent consumption of industrial garnet was 68,600 t. The United States accounted for more than 35% of global industrial garnet use.

The end uses for garnet in the United States and their estimated market share in 2004 were waterjet cutting, 35%; abrasive blasting media, 30%; water filtration, 15%; abrasive powders, 10%; and other, 10%. Domestic industries that consume garnet include aircraft and motor vehicle manufacturers, ceramics and glass producers, electronic component manufacturers, filtration plants, glass polishing, the petroleum industry, shipbuilders, textile stonewashing, and wood-furniture-finishing operations (Moore, 2006).

Most industrial garnet is used as an abrasive because of its hardness, which ranges from 6 to 7.5 on the Mohs scale. High-quality, high-value garnet grain has been used principally

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for such applications as optical lens grinding and plate-glass grinding for more than a century; industrial diamond and fused aluminum oxide are competitors in these applications. In recent years, industrial garnet powders have been used for high-quality, scratch-free lapping of semiconductor materials and other metals. Garnet has replaced some silica sand in the blast cleaning market because garnet does not have the health risks associated with the inhalation of airborne crystalline silica dust. At present, however, silica sand and mineral slag continue to be the most widely used media in blasting (Harris, 2000). The U.S. petroleum industry is one of the leading garnet-consuming industries, using garnet for cleaning drill pipes and well casings. The shipbuilding and aluminum aircraft industries use garnet for blast cleaning and for finishing metal surfaces. Similar uses include the cleaning and conditioning of aluminum and other soft metals as well as metal cleaning by structural steel fabrication shops. Garnet entrained in high-pressure streams of water also is used to cut many different materials. Garnet powders generally are used for antiskid surfaces, antislip paints, and glass/ceramic polishes.

Low-quality industrial garnet, which has lower hardness and is more highly fractured, is used as a filtration medium in water purification systems because of its relative inertness and resistance to chemical degradation. Garnet is well suited for water filtration and treatment because it is relatively heavy and chemically stable. Mixed-media water filtration, which uses a mixture of anthracite, garnet, and silica sand, has displaced older filtration methods because it provides better water quality. Garnet competes with ilmenite, magnetite, plastics, and silica sand as a filtration medium.

Other applications include the manufacture of coated abrasives and the finishing of felt, hard rubber, leather, plastics, and wood. In the coated-abrasive market, garnet falls between low-cost quartz sand or staurolite and more costly manufactured abrasives, such as fused alumina and silicon carbide. Garnet is more efficient than quartz sand in most coated-abrasive applications. Owing to its friable nature and lower hardness, garnet cannot compete with manufactured abrasives in metalworking applications that require substantial metal removal.

Prices

Industrial garnet is priced at a wide range, depending on application, quality, quantity purchased, source, and type. During 2005, domestic values for crude concentrates for different applications ranged from about $58 to $120 per metric ton, with an average for the year of $96 per ton. Domestic values for refined garnet for different applications sold during the year ranged from $61 to $298 per ton, with an average for the year of $268 per ton.

The estimated per ton values of garnet from other leading producers around the world are as follows: North America, $125 to $600; India, $60 to $120; and Australia, $90 to $145 (Rapple, 2006).

Foreign Trade

Lower priced foreign imports slowly began displacing U.S. production in domestic markets during the 1990s. Since 2003, industrial garnet imports have exceeded domestic industrial garnet production.

The U.S. Census Bureau compiles trade data on exports and imports of industrial garnet mixed with other natural abrasive commodities, such as emery and corundum, so the data cannot be identified specifically as garnet. Based on reports from some producers and other industry sources, imports and exports of industrial garnet were estimated to be 41,800 t and 13,400 t, respectively, in 2005. The level of imports increased by about 14% compared with that of 2004, and exports increased by about 22% from those of 2004. Australia provided approximately 33%, India almost 28%, China almost 26%, Canada approximately 12%, and other countries 1% of industrial garnet imported into the United States for consumption. Australia, China, and India continued to increase their exports of garnet. Garnet exported by the United States was shipped to Asian, Canadian, Caribbean, Central American, European, and South American markets. More than one-half of exports of garnet from the United States went to Canada and Mexico.

World Review

The USGS estimated total world industrial garnet production to be about 324,000 t, but some industrial garnet consultants have estimated world production to be as high as 440,000 t (Gorrill, 2003). Australia, China, India, and the United States were the leading producers in 2005. The United States produced about 12% of the industrial garnet mined worldwide. Production in both Australia and India exceeded production in the United States. Russia and Turkey have been mining garnet in recent years, primarily for domestic markets. Small garnet-mining operations also are located in Canada, Chile, the Czech Republic, Pakistan, South Africa, Spain, Thailand, and Ukraine. Production in most of these countries is for domestic use.

Australian industrial garnet production and exports have been increasing since 1998 and are expected to continue increasing. China and India also have increased garnet output in the past decade and have become significant garnet sources for other countries.

Worldwide end uses and their estimated market shares are abrasive blasting media, 60%; waterjet cutting, 20%; water filtration, 10%; and other end uses, 10%.

Outlook

Excess production capacity combined with stocks that vary in grain size, mineral type, and quality will keep prices down for the short term. Garnet producers could benefit from the enforcement of existing regulations and tighter environmental and health controls on abrasive silica blasting media. The implementation of clean water regulations in the United States and the improvement of potable water supplies in developing countries also will benefit garnet suppliers.

Worldwide industrial garnet demand is expected to continue growing during the next 5 years. Markets for waterjet cutting and blasting media are expected to exhibit the highest growth (Roskill Information Services, Ltd., 2000, p. 62, 66).

Demand for garnet polishing powders, which are used in polishing television and monitor screens, is declining with the

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emergence of flat screen systems that do not require garnet polishing during their manufacture. In coming years, as the affordability and popularity of flat screen technology increases, a further decrease in demand for garnet polishing powders is probable (Gorrill, 2003).

Recent worldwide increases in petroleum prices have stimulated an increase in exploration for petroleum resources. This exploration increase should provide opportunities for increased use of garnet blasting media for cleaning drill pipe. Increased defense spending in the United States could lead to increased garnet demand, since the aircraft manufacturing and shipbuilding industries use significant amounts of garnet for blast cleaning and finishing of metal surfaces and for use in waterjet cutting.

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TABLE 1
SALIENT U.S. INDUSTRIAL GARNET STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Crude production:						
Quantity	metric tons	52,700	38,500	29,200	28,400	40,100
Value	thousands	$6,430	$4,500	$3,170	$3,050	$3,840
Sold or used:[2]						
Quantity	metric tons	46,200	37,500	33,100	30,400	23,100
Value	thousands	$13,500	$11,100	$10,900	$10,000	$6,200
Exports:						
Quantity	metric tons	10,000	10,400	11,000	10,900	13,400
Value	thousands	$8,270	$8,930	$7,460	$8,990	$9,700
Imports for consumption:						
Quantity	metric tons	29,600 r	27,200 r	34,800 r	36,500	41,800
Value	thousands	$3,700	$3,610	$3,710	$4,260	$5,910
Apparent consumption[3]	metric tons	72,300 r	55,300 r	53,000 r	54,000 r	68,600
World, production e	do.	283,000	277,000	277,000	302,000	324,000

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits.

[2]May exclude some unreported exports.

[3]Domestic production plus imports minus exports.

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GEMSTONES

By Donald W. Olson

Domestic survey data and tables were prepared by Nicholas A. Muniz, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

In 2005, the estimated value of natural gemstones produced in the United States was more than $13.4 million, and the estimated value of U.S. laboratory-created gemstone production was more than $51.1 million. The total estimated value of U.S. gemstone production was almost $64.6 million. The value of U.S. gemstone imports was $17.2 billion, and the value of combined U.S. gemstone exports and reexports was estimated to be $8.85 billion.

In this report, the terms "gem" and "gemstone" mean any mineral or organic material (such as amber, pearl, petrified wood, and shell) used for personal adornment, display, or object of art because it possesses beauty, durability, and rarity. Of more than 4,000 mineral species, only about 100 possess all these attributes and are considered to be gemstones. Silicates other than quartz are the largest group of gemstones in terms of chemical composition; oxides and quartz are the second largest (table 1). Gemstones are subdivided into diamond and colored gemstones, which in this report designates all natural nondiamond gems. In addition, laboratory-created gemstones, cultured pearls, and gemstone simulants are discussed but are treated separately from natural gemstones (table 2). Trade data in this report are from the U.S. Census Bureau. All percentages in the report were computed using unrounded data. Current information on industrial-grade diamond and industrial-grade garnet can be found in the U.S. Geological Survey (USGS) Minerals Yearbook, volume I, Metals and Minerals chapters on industrial diamond and industrial garnet, respectively.

Gemstones have fascinated humans since prehistoric times. They have been valued as treasured objects throughout history by all societies in all parts of the world. Amber, amethyst, coral, diamond, emerald, garnet, jade, jasper, lapis lazuli, pearl, rock crystal, ruby, serpentine, and turquoise are some of the first stones known to have been used for making jewelry. These stones served as symbols of wealth and power. Today, gems are worn more for pleasure or in appreciation of their beauty than to demonstrate wealth. In addition to jewelry, gemstones are used for collections, decorative art objects, and exhibits.

Legislation and Governments Programs

The Clean Diamond Trade Act was signed into law on April 25, 2003, by the President. This law provided the effective measures to stop trade in conflict diamonds in the United States, and its enactment made the United States a full participant in the Kimberley Process Certification Scheme (KPCS) (U.S. House of Representatives, 2003§). U.S. participation in the KPCS is critical to its success in excluding conflict diamonds from the legitimate supply chain because the United States is the world's leading gem-quality diamond market. The industry and trade associations have played an active role in achieving this progress in ending the problem of conflict diamonds (Professional Jeweler, 2003§[1]).

Production

U.S. gemstone production data were based on a survey of more than 230 domestic gemstone producers conducted by the USGS. The survey provided a foundation for projecting the scope and level of domestic gemstone production during the year. However, the USGS survey did not represent all gemstone activity in the United States, which includes thousands of professional and amateur collectors. Consequently, the USGS supplemented its survey with estimates of domestic gemstone production from related published data, contacts with gemstone dealers and collectors, and information garnered at gem and mineral shows.

Commercial mining of gemstones has never been extensive in the United States. More than 60 varieties of gemstones have been produced commercially from domestic mines, but most of the deposits have been relatively small compared with other mining operations. In the United States, much of the current gemstone mining is conducted by individual collectors, gem clubs, and hobbyists rather than by businesses.

The commercial gemstone industry in the United States consists of individuals and companies that mine gemstones or harvest shell and pearl, firms that manufacture laboratory-created gemstones, and individuals and companies that cut and polish natural and laboratory-created gemstones. The domestic gemstone industry is focused on the production of colored gemstones and on the cutting and polishing of large diamond stones. Industry employment is estimated to range from 1,000 to 1,500 workers (U.S. International Trade Commission, 1997, p. 1).

Most natural gemstone producers in the United States are small businesses that are widely dispersed and operate independently. The small producers probably have an average of less than three employees, including those who only work part time. The number of gemstone mines operating from year to year fluctuates because the uncertainty associated with the discovery and marketing of gem-quality minerals makes it difficult to obtain financing for developing and sustaining economically viable operations (U.S. International Trade Commission, 1997, p. 23).

The total value of natural gemstones produced in the United States during 2005 was estimated to be more than $13.4 million (table 3). The production value decreased by 7% from that of the preceding year.

Natural gemstone materials indigenous to the United States are collected, produced, and/or marketed in every State. During

[1]References that include a section mark (§) are found in the Internet References Cited section.

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2005, all 50 States produced at least $1,000 worth of gemstone materials. Seven States accounted for 78% of the total value, as reported by survey respondents. These States, in order of declining value of production, were Tennessee, Arizona, Oregon, California, Arkansas, Montana, and Nevada. Some States were known for the production of a single gemstone material—Tennessee for freshwater pearls, for example. Other States produced a variety of gemstones, for example Arizona's gemstone deposits included agate, amethyst, azurite, chrysocolla, garnet, jade, jasper, malachite, obsidian, onyx, opal, peridot, petrified wood, smithsonite, and turquoise. There is also a wide variety of gemstones found and produced in California, Idaho, Montana, and North Carolina.

During 2005, the United States had only one operation in known diamond-bearing areas from which diamonds were produced. That diamond operation is in Crater of Diamonds State Park near Murfreesboro in Pike County, AR, where a dig-for-fee operation for tourists and rockhounds is maintained by the State of Arkansas. Crater of Diamonds is the only diamond mine in the world that is open to the public. The diamonds occur in a lamproite breccia tuff associated with a volcanic pipe and in the soil developed from the lamproite breccia tuff. In 2005, 536 diamond stones with an average weight of 0.193 carats were recovered at the Crater of Diamonds State Park. Since the diamond-bearing pipe and the adjoining area became a State park in 1972, 25,369 diamond stones with a total carat weight of 4,954.41 have been recovered (Tom Stolarz, park superintendent, Crater of Diamonds State Park, written commun., January 31, 2006). Exploration has demonstrated that there is about 78.5 million metric tons (Mt) of diamond-bearing rock in this diamond deposit (Howard, 1999, p. 62). An Arkansas law enacted early in 1999 prohibits commercial diamond mining in the park (Diamond Registry Bulletin, 1999).

There have been no commercially operated diamond mines in the United States since 2002. Diamond was produced at the Kelsey Lake diamond mine, located close to the Colorado-Wyoming State line near Fort Collins, CO, for several years until April 2002. The Kelsey Lake property includes nine known kimberlite pipes, three of which have been tested and have shown that diamonds are present. The remaining six pipes have yet to be fully explored and tested for their diamond potential. Of the diamonds recovered, 35% to 50% was industrial grade. The identified resources are at least 17 Mt grading an average of 4 carats per 100 metric tons (Taylor Hard Money Advisers, 2000§).

Studies by the Wyoming Geological Survey have shown that Wyoming has the potential for a $1 billion diamond mining business. Twenty diamondiferous kimberlite pipes and one diamondiferous mafic breccia pipe have been identified in southern Wyoming. Two of the largest kimberlite fields, State Line and Iron Mountain, and the largest lamproite field in the United States, Leucite Hills, are in Wyoming. Several diamond mining firms have been interested in the southern Wyoming and northern Colorado area, but the only diamond mine developed in the area thus far is the Kelsey Lake Mine (Associated Press, 2002§).

The success of Canadian diamond mines has stimulated interest in exploring for commercially feasible diamond deposits in the United States outside of Wyoming and Colorado. Australian and Canadian companies are now conducting diamond exploration in Alaska and Minnesota. Alaska has some similar geologic terrain to the Northwest Territories of Canada; in addition, certain varieties of garnet and other diamond indicator minerals as well as 17 microscopic diamonds have been found near Anchorage, AK. Two Canadian companies have invested $1 million in an exploratory drilling program. Geologists from the University of Minnesota teamed with an Australian mining company and were conducting a soil sampling program in Minnesota for mineral exploration, including diamond. The samples were being analyzed by Australia's WMC Resources Ltd. The scientists thought that there is a good chance of success owing to similarities between the geology in Minnesota and Canada (Diamond Registry Bulletin, 2005a).

In another exploration venture, Delta Mining and Exploration Corp. found a diamond-bearing kimberlite in an 32.4-hectare (80-acre) site known as the Homestead property near Lewistown, MT. Preliminary tests have shown the presence of microscopic diamonds. The company was planning a $700,000 soil sampling program as further exploration. Diamonds have been found in the stream beds and glacial valleys of Montana for years (Associated Press, 2004§).

In addition to natural gemstones, laboratory-created gemstones and gemstone simulants are produced in the United States. Laboratory-created or synthetic gemstones have the same chemical, optical, and physical properties as the natural materials. Simulants have an appearance similar to that of a natural gemstone material, but they have different chemical, optical, and physical properties. Laboratory-created gemstones produced in the United States include alexandrite, diamond, emerald, moissanite, ruby, sapphire, and turquoise. Simulants of coral, lapis lazuli, malachite, and turquoise also are manufactured in the United States. In addition, certain colors of laboratory-created sapphire and spinel, used to represent other gemstones, are classified as simulants.

Laboratory-created gemstone production in the United States was valued at more than $51.1 million during 2005; simulant gemstone output was even greater and was estimated to be valued at more than $100 million. Five companies in five States, representing virtually the entire U.S. laboratory-created gemstone industry, reported production to the USGS. The States with reported laboratory-created gemstone production, in descending order of production value, were North Carolina, Florida, Massachusetts, Michigan, and Arizona.

Gemesis Corp., a company in Sarasota, FL, consistently produced gem-quality laboratory-created diamond and reported a sixth year of production in 2005. The laboratory-created diamonds are produced using equipment, expertise, and technology developed by a team of scientists from Russia and the University of Florida. The weight of the laboratory-created diamond stones range from 1.5 to 2 carats, and most of the stones are yellow, brownish yellow, colorless, and green (Weldon, 1999§). Gemesis uses diamond-growing machines, each machine capable of growing 3-carat rough diamonds by generating high-pressure, high-temperature (HPHT) conditions that recreate the conditions in the Earth's mantle where natural diamonds form. Gemesis eventually plans to have 250 diamond-

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growing machines installed at the facility near Sarasota, FL (Davis, 2003); at that point, Gemesis could be producing as much as 30,000 to 40,000 stones each year, and annual revenues may reach $70 million to $80 million (Diamond Registry Bulletin, 2001). Gemesis diamonds became available for retail purchase in jewelry stores and on the Internet in fall 2003. The prices of the Gemesis laboratory-created diamonds are below those of natural diamond but above the prices of simulated diamond (Weldon, 2003§).

Apollo Diamond, Inc., near Boston, MA, has developed and patented a method for growing extremely pure, gem-quality diamond with flawless crystal structure by chemical vapor deposition (CVD). The CVD technique transforms carbon into plasma, which is then precipitated onto a substrate as diamond. CVD has been used for more than a decade to cover large surfaces with microscopic diamond crystals, but until this process, no one had discovered the combination of temperature, gas composition, and pressure that resulted in the growth of a single diamond crystal. CVD diamond precipitates as nearly 100% pure, almost flawless diamond, and therefore may not be distinguishable from natural diamond by some tests (Davis, 2003). In 2005, Apollo Diamond produced stones that range from 1 to 2 carats and expected to expand to larger stones in the future (Maney, 2005§). The company planned to start selling diamonds in the jewelry market at costs 10% to 30% below those of comparable natural diamonds (Hastings, 2005). Apollo planned to open the Apollo Diamond Web store to the general public in 2006 (Apollo Diamond, Inc., 2005§). Besides its use as a gemstone, CVD diamond's highest value is as a material for high-tech uses, such as in computer technology (Maney, 2005§).

In early 2004, scientists at the Carnegie Institution of Washington's Geophysical Laboratory published the results of a study in which researchers grew diamond crystals by a special CVD process at very high growth rates. They were able to grow gem-sized crystals in a day—a growth rate 100 times faster than other methods used before. This is a new way of producing diamond crystals for such new applications as diamond-base electronic devices and next generation cutting tools (Willis, 2004). By early 2005, the Geophysical Laboratory and the University of Alabama had jointly developed and patented the CVD process and apparatus to produce ½-inch-thick 10-carat single diamond crystals at very rapid growth rates (100 micrometers per hour). This faster CVD method uses microwave plasma technology and allows multiple crystals to be grown simultaneously. This size is about five times that of commercially available laboratory-created diamonds produced by HPHT methods and other CVD techniques. Dr. Russell Hemley, a researcher at the Carnegie Institution, stated, "High-quality crystals over 3 carats are very difficult to produce using the conventional approach. Several groups have begun to grow diamond single crystals by CVD, but large, colorless, and flawless ones remain a challenge. Our fabrication of 10-carat, half-inch CVD diamonds is a major breakthrough" (Willis, 2004; Carnegie Institution of Washington, 2005; Science Blog, 2005§).

Both Apollo Diamond and the Carnegie Institution have noted that their diamonds produced by the CVD method are harder than natural diamonds and diamonds produced by HPHT methods.

In 2005, the North Carolina company Charles & Colvard, Ltd. entered its eighth year of producing and marketing moissanite, a gem-quality laboratory-created silicon carbide. Moissanite is also an excellent diamond simulant, but it is being marketed for its own gem qualities. Moissanite exhibits a higher refractive index (brilliance) and higher luster than diamond. Its hardness is between those of corundum (ruby and sapphire) and diamond, which gives it durability (Charles & Colvard, Ltd., 2005§).

Although U.S. shell production decreased by 11% in 2005 compared with that of 2004, shell is not expected to ever be the large segment of U.S. gemstone production it was for several years in the past. U.S. shell material from mussels is used as seed material for culturing pearls. The lower shell production is owing to overharvesting in past years, the killing off of U.S. native mussel species by invasive exotic species, and a decline in market demand. During the past 10 years, the United States has lost about three-quarters of the native mussel population, and one-half of the approximately 300 total U.S. native mussel species are now listed as endangered species. The zebra mussel is the invasive exotic species that has done most of the damage, and it has been introduced into U.S. rivers and waterways in discharged ballast water from transoceanic ships (Iowa Department of Natural Resources, 2001§; Scott Gritterf, fisheries biologist, Iowa Department of Natural Resources, oral commun., November 14, 2002). The market still has not completely recovered from the die-off of Japanese oysters. Seed material had been stockpiled in Japan, and now producers in Japan are using manmade seed materials or seed materials from China and other sources in addition to the stockpiled material. There also has been an increase in the popularity of darker and colored pearls that do not use U.S. seed material (Ted Kroll, assistant director of fisheries, Kentucky Department of Fish and Wildlife, oral commun., November 15, 2002). In some regions of the United States, shell from mussels is beginning to be used as a gemstone based on its own merit rather than as seed material for pearls. This shell material is being used in beads, jewelry, and watch faces.

Consumption

Although the United States accounted for little of the total global gemstone production, it was the world's leading gemstone market. U.S. gemstone markets accounted for more than an estimated 35% of world gemstone demand in 2005. The U.S. market for unset gem-quality diamond during the year was estimated to have exceeded $16.2 billion. Domestic markets for natural, unset nondiamond gemstones totaled more than $996 million.

In the United States, about two-thirds of domestic consumers designate diamond as their favorite gemstone when surveyed. In 2005, the top 10 selling colored gemstones, in descending order, were blue sapphire; ruby; blue topaz; fancy sapphire; amethyst; peridot; tanzanite; emerald; aquamarine, citrine, and opal (tied for ninth place); and rhodolite garnet. Pink tourmaline and pearl dropped out of the top 10 from the previous year. During 2005, 50% of the jewelry retailers said their sales were up compared with 45% of retailers in 2004 (Prost, 2005; Wade, 2006). U.S. retail jewelry sales reached approximately $60 billion in

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2005, with about 56% of that value involving diamond jewelry (SeekingAlpha, 2006§). U.S. online jewelry sales increased by more than 25% in 2005 to nearly $2.1 billion; this represents about 3.5% of all jewelry sold in the United States (IDEX Magazine, 2006§). The U.S. market accounted for more than 50% of the global diamond jewelry retail market in 2005.

The U.S. colored gemstone market posted an overall increase in sales during 2005 compared with the previous year's sales. The popularity of colored gemstones, colored laboratory-created gemstones, and "fancy" colored diamonds continued to increase in 2005. This was indicated by increased values of U.S. imports for consumption in most colored stone categories (emerald, coral, rubies, sapphires, other precious and semiprecious stones, and laboratory-created gems) in 2005 compared with the values from the previous year (table 10). Colored stone popularity also was evidenced by their general sales increase in 2005 (Wade, 2006).

The Gemological Institute of America (GIA) terminated the employment of four of its graders for improprieties in its New York, NY, laboratory, and the lab chief resigned. The improprieties were violations of the GIA code of ethics by clients of the lab, in particular, improper attempts to influence the outcome of grading reports. GIA is the world's foremost authority in gemology, diamond and gem grading and identification, jewelry education, and gemology research. The majority of GIA employees remain above reproach, and the GIA remains the leading lab in the industry. The incident had the potential to damage confidence in gem grading, but because of a thorough and immediate investigation into the situation, that did not happen (Diamond Registry Bulletin, 2005c, f).

Prices

Gemstone prices are governed by many factors and qualitative characteristics, including beauty, clarity, defects, demand, durability, and rarity. Diamond pricing, in particular, is complex; values can vary significantly depending on time, place, and the subjective valuations of buyers and sellers. There are more than 14,000 categories used to assess rough diamond and more than 100,000 different combinations of carat, clarity, color, and cut values used to assess polished diamond (Pearson, 1998).

Colored gemstone prices are generally influenced by market supply and demand considerations, and diamond prices are supported by producer controls on the quantity and quality of supply. Values and prices of gemstones produced and/or sold in the United States are listed in tables 3 through 5. In addition, customs values for diamonds and other gemstones imported, exported, or reexported are listed in tables 6 through 10.

De Beers Group companies are a significant force affecting the price of gem-quality diamond worldwide because they mine more than 40% of the gem-quality diamond produced each year (De Beers Group, 2005§). De Beers companies also sort and valuate about two-thirds (by value) of the world's annual supply of rough diamond through De Beers' subsidiary Diamond Trading Co. (DTC), which has marketing agreements with other producers (De Beers Group, 2003§).

The yearly average diamond price index of the Diamond High Council of Antwerp increased in 2005 by 7.8% to 330.4 for 1-carat diamonds and by 1.3% to 262.2 for ½-carat diamonds. The diamond price index measures price changes relative to the baseline of 100 set by the 1985 price (Diamond Registry Bulletin, 2006c).

Foreign Trade

During 2005, total U.S. gemstone trade with all countries and territories was valued at more than $26.0 billion, which was an increase of 17.7% from that of the previous year. Diamond accounted for about 95% of the 2005 gemstone trade total. In 2005, U.S. exports and reexports of diamond were shipped to 89 countries and territories, and imports of all gemstones were received from 103 countries and territories (tables 6-10). During 2005, U.S. trade in cut diamond and unworked diamond increased by 14.6% and 21.9% respectively, compared with the previous year. The United States remained the world's leading diamond importer. The United States is a significant international diamond transit center as well as the world's leading gem-quality diamond market. The large volume of reexports shipped to other centers reveals the significance that the United States has in the world's diamond supply network (table 6).

Trade in laboratory-created gemstone increased by 0.3% for the United States in 2005 compared with the previous year. Laboratory-created gemstone imports from Austria, China, France, Germany, Hong Kong, Sri Lanka, Switzerland, and Thailand made up almost 93% (by value) of the total domestic imports of laboratory-created gemstones during the year. Prices of certain imported laboratory-created gemstones, such as amethyst, were very competitive. The marketing of imported laboratory-created gemstones and enhanced gemstones as natural gemstones and the mixing of laboratory-created materials with natural stones in imported parcels continued to be problems for some domestic producers in 2005. There also were problems with some simulants being marketed as laboratory-created gemstones during the year.

World Industry Structure

The gemstone industry worldwide has two distinct sectors—diamond mining and marketing and colored gemstone production and sales. Most diamond supplies are controlled by a few major mining companies; prices are supported by managing the quality and quantity of the gemstones relative to demand, a function performed by De Beers through DTC. Unlike diamond, colored gemstones are primarily produced at relatively small, low-cost operations with few dominant producers; prices are influenced by consumer demand and supply availability.

In 2005, world natural diamond production totaled about 183 million carats—102 million carats gem quality and 81.0 million carats industrial grade (table 11). Most production was concentrated in a few regions—Africa [Angola, Botswana, Congo (Kinshasa), Namibia, and South Africa], Asia (northeastern Siberia and Yakutia in Russia), Australia, North America (Northwest Territories in Canada), and South America (Brazil and Venezuela). In 2005, Australia led the world in total diamond output quantity (combined gemstone and industrial).

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Botswana was the world's leading gemstone diamond producer, followed by Russia, Australia, Canada, Congo (Kinshasa), South Africa, and Angola in descending quantity order. These seven countries produced 95.1% of the world's gemstone diamond output in 2005.

De Beers reported that its sales of rough diamond for 2005 were $6.54 billion, which was up by 15% from $5.7 billion in 2004 (Diamond Registry Bulletin, 2004a, 2005b, 2006b).

In 2002, the international rough-diamond certification system KPCS was implemented to solve the problem of conflict diamonds—rough diamonds used by rebel forces and their allies in several countries to help finance warfare aimed at subverting governments recognized as legitimate by the United Nations (UN). The KPCS was agreed upon by UN member nations, the diamond industry, and involved nongovernmental organizations. The KPCS includes the following key elements: the use of forgery-resistant certificates and tamper-proof containers for shipments of rough diamonds; internal controls and procedures that provide credible assurance that conflict diamonds do not enter the legitimate diamond market; a certification process for all exports of rough diamonds; the gathering, organizing, and sharing of import and export data on rough diamonds with other participants of relevant production; credible monitoring and oversight of the international certification scheme for rough diamonds; effective enforcement of the provisions of the certification scheme through dissuasive and proportional penalties for violations; self regulation by the diamond industry that fulfills minimum requirements; and sharing information with all other participants on relevant rules, procedures, and legislation as well as examples of national certificates used to accompany shipments of rough diamonds (Weldon, 2001§). Canada acted as the chair and secretariat of the KPCS for the first 2 years, and in October 2004, Russia assumed these duties. For the KPCS to be fully implemented, all participating countries must pass the necessary laws to carry it out. In 2005, Indonesia and Lebanon joined the list of countries participating in the KPCS, amounting to a total of 45 nations that have signed the agreement; participating nations in the KPCS account for approximately 98% of the global production and trade of rough diamonds (Diamond Registry Bulletin, 2005h; Kimberley Process, 2005§). Discussions about the possible participation of several other countries are ongoing.

Worldwide, the value of production of natural gemstones other than diamond was estimated to have exceeded $2 billion in 2005. Most nondiamond gemstone mines are small, low-cost, and widely dispersed operations in remote regions of developing nations. Foreign countries with major gemstone deposits other than diamond are Afghanistan (aquamarine, beryl, emerald, kunzite, lapis lazuli, ruby, and tourmaline), Australia (beryl, opal, and sapphire), Brazil (agate, amethyst, beryl, ruby, sapphire, topaz, and tourmaline), Burma (beryl, jade, ruby, sapphire, and topaz), Colombia (beryl, emerald, and sapphire), Kenya (beryl, garnet, and sapphire), Madagascar (beryl, rose quartz, sapphire, and tourmaline), Mexico (agate, opal, and topaz), Sri Lanka (beryl, ruby, sapphire, and topaz), Tanzania (garnet, ruby, sapphire, tanzanite, and tourmaline), and Zambia (amethyst and beryl). In addition, pearls are cultured throughout the South Pacific and in other equatorial waters; Australia, China, French Polynesia, and Japan are key producers.

World Review

Canada.—The Ekati Diamond Mine, Canada's first operating commercial diamond mine, completed its seventh full year of production. In 2005, Ekati produced 3.23 million carats of diamond from 4.44 Mt of ore (BHP Billiton Ltd., 2006b). BHP Billiton Ltd. has an 80% controlling ownership in Ekati, which is in the Northwest Territories. Ekati has estimated reserves of 60.3 Mt of ore in kimberlite pipes that contain 54.3 million carats of diamond, and BHP Billiton projected the mine life to be 25 years. The Ekati Mine is now producing from the Koala, Panda, and Misery kimberlite pipes. BHP Billiton is using underground mining techniques to recover diamonds from deeper portions of the Panda kimberlite pipe (BHP Billiton Ltd., 2004). Underground mining of the deeper portions of the Koala kimberlite pipe has been approved and is expected to begin in December 2007 (BHP Billiton Ltd., 2006a). The Koala and Panda kimberlite pipes were first open pit mined (Diamond Registry Bulletin, 2002). Approximately one-third of the Ekati diamond production is industrial-grade material (Darren Dyck, senior project geologist, BHP Diamonds, Inc., oral commun., May 27, 2001).

The Diavik Diamond Mine, also in the Northwest Territories, completed its third full year of production. In 2005, Diavik produced 8.3 million carats of diamond from its A154 North ore body and the adjacent A154 South pipe. Both pipes are located within the same pit (Diavik Diamond Mines Inc., 2006). Diavik has estimated the mine's remaining proven and probable reserves to be 29.8 Mt of ore in kimberlite pipes, containing 95.6 million carats of diamond, and projected the mine life to be 16 to 22 years (Diavik Diamond Mines Inc., 2005). The mine is an unincorporated joint venture between Diavik Diamond Mines Inc. (60%) and Aber Diamond Mines Ltd. (40%). The mine is expected to produce a total of about 107 million carats of diamond at a rate of 8 million carats per year worth about $63 per carat during the entire mine life, which began production in December 2002 (Diavik Diamond Mines Inc., 2000, p. 10-12).

Diamond exploration is continuing in Canada, with several other commercial diamond projects and additional discoveries located in Alberta, British Columbia, the Northwest Territories, the Nunavut Territory, Ontario, and Quebec. Canada produced about 7% of the world's combined natural gemstone and industrial diamond production in 2005. Canadian diamond discoveries continue to be made and production continues to increase, and Canada is now fourth ranked in production of gemstone diamond after Botswana, Russia, and Australia.

Guyana.—A report by Partnership Africa Canada (PAC) stated that nearly 20% of diamonds mined in Guyana evade the KPSC by being smuggled to Brazil and cited weak controls in Brazil and Venezuela as the problem. The situation exposes the entire industry to laundered diamonds from other countries, such as Côte d'Ivoire and Congo (Kinshasa). The report called for the expulsion of Brazil and Venezuela from the KPSC if the situation is not corrected (Diamond Registry Bulletin, 2006a).

Israel.—Polished diamond net exports for the 12-month period through October 2005 increased by 4.2% to $6.33 billion compared with the same period in 2004, and exports of rough diamond increased by 22.2% to $3 billion for the same period. Polished diamond net imports for the first 10 months

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of 2005 decreased by 18.4% to $264 million compared with those of the first 10 months of 2004, while net imports of rough diamond increased by 2.2% to $4.5 billion for the same 10-month period (Diamond Registry Bulletin, 2005d). The United States remained the leading diamond trading partner for Israel (Diamond Registry Bulletin, 2005e).

Russia.—Diamond production figures were released for the first time in December 2004. Production information had been kept as a state secret since the first diamond discovery in Siberia in 1955 (Diamond Registry Bulletin, 2005g).

Sierra Leone.—During the civil war in Sierra Leone, official diamond exports had plunged to $1.5 million a year. However, since the implementation of the KPSC and the end of the civil war diamond exports for 2005 were reported at $142 million (Diamond Registry Bulletin, 2006d).

Outlook

There are indications that there may be continued growth in the U.S. diamond and jewelry markets in 2006. Historically, diamonds have proven to hold their value despite wars or economic depressions (Schumann, 1998, p. 8).

Independent producers, such as Argyle Diamond Mines in Australia and Ekati and Diavik in Canada, will continue to bring a greater measure of competition to global markets. More competition presumably will bring more supplies and lower prices. Further consolidation of diamond producers and larger amounts of rough diamond being sold outside DTC will continue as the diamond industry adjusts to De Beers' reduced influence on the industry.

More laboratory-created gemstones, simulants, and treated gemstones will enter the marketplace and necessitate more transparent trade industry standards to maintain customer confidence.

During 2005, online sales rose by 25%, representing 3.5% of all retail jewelry sales for the year, and Internet sales of diamonds, gemstones, and jewelry will continue to grow and increase in popularity, as will other forms of e-commerce that emerge to serve the diamond and gemstone industry. This will take place as the gemstone industry and its customers become more comfortable with and learn the applications of new e-commerce tools (Diamond Registry Bulletin, 2004b, c; IDEX Magazine, 2006§).

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TABLE 1
GUIDE TO SELECTED GEMSTONES AND GEM MATERIALS USED IN JEWELRY

Name	Composition	Color	Practical size[1]	Cost[2]	Mohs	Specific gravity	Refraction	Refractive index	May be confused with	Recognition characteristics
Amber	Hydrocarbon	Yellow, red, green, blue	Any	Low to medium	2.0-2.5	1.0-1.1	Single	1.54	Synthetic or pressed plastics, kaurigum	Fossil resin, color, low density, soft and trapped insects.
Apatite	Chlorocalcium phosphate	Colorless, pink, yellow, green, blue, violet	Small	Low	5.0	3.16-3.23	Double	1.63-1.65	Amblygonite, andalusite, brazilianite, precious beryl, titanite, topaz, tourmaline	Crystal habit, color, hardness, appearance.
Azurite	Copper carbonate hydroxide	Azure, dark blue, pale blue	Small to medium	do.	3.5-4.0	3.7-3.9	do.	1.72-1.85	Dumortierite, hauynite, lapis lazuli, lazulite, sodalite	Color, softness, crystal habits and associated minerals.
Benitoite	Barium titanium silicate	Blue, purple, pink, colorless	do.	High	6.0-6.5	3.64-3.68	do.	1.76-1.80	Sapphire, tanzanite, blue diamond, blue tourmaline, cordierite	Strong blue in ultraviolet light.
Beryl:										
Aquamarine	Beryllium aluminum silicate	Blue-green to light blue	Any	Medium to high	7.5-8.0	2.63-2.80	do.	1.58	Synthetic spinel, blue topaz	Double refraction, refractive index.
Bixbite	do.	Red	Small	Very high	7.5-8.0	2.63-2.80	do.	1.58	Pressed plastics, tourmaline	Refractive index.
Emerald, natural	do.	Green	Medium	do.	7.5	2.63-2.80	do.	1.58	Fused emerald, glass, tourmaline, peridot, green garnet doublets	Emerald filter, dichroism, refractive index.
Emerald, synthetic	do.	do.	Small	High	7.5-8.0	2.63-2.80	do.	1.58	Genuine emerald	Lack of flaws, brilliant fluorescence in ultraviolet light.
Golden (heliodor)	do.	Yellow to golden	Any	Low to medium	7.5-8.0	2.63-2.80	do.	1.58	Citrine, topaz, glass, doublets	Weak-colored.
Goshenite	do.	Colorless	do.	Low	7.5-8.0	2.63-2.80	do.	1.58	Quartz, glass, white sapphire, white topaz	Refractive index.
Morganite	do.	Pink to rose	do.	do.	7.5-8.0	2.63-2.80	do.	1.58	Kunzite, tourmaline, pink sapphire	Do.
Calcite:										
Marble	Calcium carbonate	White, pink, red, blue, green, or brown	do.	do.	3.0	2.72	Double (strong)	1.49-1.66	Silicates, banded agate, alabaster gypsum	Translucent.
Mexican onyx	do.	do.	do.	do.	3.0	2.72	do.	1.60	do.	Banded, translucent.
Charoite	Hydrated sodium calcium hydroxi-fluoro-silicate	Lilac, violet, or white	Small to medium	do.	5.0-6.0	2.54-2.78	XX	1.55-1.56	Purple marble	Color, locality.
Chrysoberyl:										
Alexandrite	Beryllium aluminate	Green by day light, red by artificial light	Small (CIS[3]); medium (Sri Lanka)	High	8.5	3.50-3.84	Double	1.75	Synthetic	Strong dichroism, color varies from red to green, hardness.

See footnotes at end of table.

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TABLE 1—Continued
GUIDE TO SELECTED GEMSTONES AND GEM MATERIALS USED IN JEWELRY

Name	Composition	Color	Practical size[1]	Cost[2]	Mohs	Specific gravity	Refraction	Refractive index	May be confused with	Recognition characteristics
Chrysoberyl—Continued:										
Cats-eye	Beryllium aluminate	Greenish to brownish	Small to large	High	8.5	3.50-3.84	Double	1.75	Synthetic, shell	Density, translucence, chatoyance.
Chrysolite	do.	Yellow, green, and/or brown	Medium	Medium	8.5	3.50-3.84	do.	1.75	Tourmaline, peridot	Refractive index, silky.
Chrysocolla	Hydrated copper silicate	Green, blue	Any	Low	2.0-4.0	2.0-2.4	XX	1.46-1.57	Azurite, dyed chalcedony, malachite, turquoise, variscite	Lack of crystals, color, fracture, low density and softness.
Coral	Calcium carbonate	Orange, red, white, black, purple, or green	Branching, medium	do.	3.5-4.0	2.6-2.7	Double	1.49-1.66	False coral	Dull translucent.
Corundum:										
Ruby	Aluminum oxide	Rose to deep purplish red	Small	Very high	9.0	3.95-4.10	do.	1.78	Synthetics, including spinel, garnet	Inclusions, fluorescence.
Sapphire, blue	do.	Blue	Medium	High	9.0	3.95-4.10	do.	1.78	do.	Inclusions, double refraction, dichroism.
Sapphire, fancy	do.	Yellow, pink, colorless, orange, green, or violet	Medium to large	Medium	9.0	3.95-4.10	do.	1.78	Synthetics, glass and doublets, morganite	Inclusions, double refreaction, refractive index.
Sapphire or ruby, stars	do.	Red, pink, violet, blue, or gray	do.	High to low	9.0	3.95-4.10	do.	1.78	Star quartz, synthetic stars	Shows asterism, color side view.
Sapphire or ruby, synthetic	do.	Yellow, pink, or blue	Up to 20 carats	Low	9.0	3.95-4.10	do.	1.78	Synthetic spinel, glass	Curved striae, bubble inclusions.
Cubic zirconia	Zirconium and yttrium oxides	Colorless, pink, blue, lavender, yellow	Small	do.	8.25-8.5	5.8	Single	2.17	Diamond, zircon, titania, moissanite	Hardness, density, lack of flaws and inclusions, refractive index.
Diamond	Carbon	White, blue-white, yellow, brown, green, red, pink, blue	Any	Very high	10.0	3.516-3.525	do.	2.42	Zircon, titania, cubic zirconia, moissanite	High index, dispersion, hardness, luster.
Feldspar:										
Amazonite	Alkali aluminum silicate	Green-blue	Large	Low	6.0-6.5	2.56	XX	1.52	Jade, turquoise	Cleavage, sheen, vitreous to pearly, opaque, grid.
Labradorite	do.	Gray with blue and bronze sheen color play (schiller)	do.	do.	6.0-6.5	2.56	XX	1.56	do.	Do.
Moonstone	do.	Colorless, white, gray, or yellow with white, blue, or bronze schiller	do.	do.	6.0-6.5	2.77	XX	1.52-1.54	Glass, chalcedony, opal	Pale sheen, opalescent.
Sunstone	do.	Orange, red brown, colorless with gold or red glittery schiller	Small to medium	do.	6.0-6.5	2.77	XX	1.53-1.55	Aventurine, glass	Red glittery schiller.

See footnotes at end of table.

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TABLE 1—Continued
GUIDE TO SELECTED GEMSTONES AND GEM MATERIALS USED IN JEWELRY

Name	Composition	Color	Practical size[1]	Cost[2]	Mohs	Specific gravity	Refraction	Refractive index	May be confused with	Recognition characteristics
Garnet	Complex silicate	Brown, black, yellow, green, red, or orange	Small to medium	Low to high	6.5-7.5	3.15-4.30	Single strained	1.79-1.98	Synthetics, spinel, glass	Single refraction, anomalous strain.
Hematite	Iron oxide	Black, black-gray, brown-red	Medium to large	Low	5.5-6.5	5.12-5.28	XX	2.94-3.22	Davidite, cassiterite, magnetite, neptunite, pyrolusite, wolframite	Crystal habit, streak, hardness.
Jade:										
Jadeite	Complex silicate	Green, yellow, black, white, or mauve	Large	Low to very high	6.5-7.0	3.3-3.5	Crypto-crystalline	1.65-1.68	Nephrite, chalcedony, onyx, bowenite, vesuvianite, grossularite	Luster, spectrum, translucent to opaque.
Nephrite	Complex hydrous silicate	do.	do.	do.	6.0-6.5	2.96-3.10	do.	1.61-1.63	Jadeite, chalcedony, onyx, bowenite, vesuvianite, grossularite	Do.
Jet (gagate)	Lignite	Deep black, dark brown	do.	Low	2.5-4.0	1.19-1.35	XX	1.64-1.68	Anthracite, asphalt, cannel coal, onyx, schorl, glass, rubber	Luster, color.
Lapis lazuli	Sodium calcium aluminum silicate	Dark azure-blue to bright indigo blue or even a pale sky blue.	do.	do.	5.0-6.0	2.50-3.0	XX	1.50	Azurite, dumortierite, dyed howlite, lazulite, sodalite, glass	Color, crystal habit, associated minerals, luster, and localities.
Malachite	Hydrated copper carbonate	Light to black-green banded	do.	do.	3.5-4.0	3.25-4.10	XX	1.66-1.91	Brochantite, chrysoprase, opaque green gemstones	Color banding, softness, associated minerals.
Moissanite	Silicon carbide	Colorless and pale shades of green, blue, yellow	Small	Low to medium	9.25	3.21	Double	2.65-2.69	Diamond, zircon, titania, cubic zirconia	Hardness, dispersion, lack of flaws and inclusions, refractive index.
Obsidian	Amorphous, variable (usually felsic)	Black, gray, brown, dark green, white, transparent	Large	Low	5.0-5.5	2.35-2.60	XX	1.45-1.55	Aegirine-augite, gadolinite, gagate, hematite, pyrolusite, wolframite	Color, conchoidal fracture, flow bubbles, softness, and lack of crystal faces.
Opal	Hydrated silica	Reddish orange, colors flash in white gray, black, red, or yellow	do.	Low to high	5.5-6.5	1.9-2.3	Single	1.45	Glass, synthetics, triplets, chalcedony	Color play (opalescence).
Peridot	Iron magnesium silicate	Yellow and/or green	Any	Medium	6.5-7.0	3.27-3.37	Double (strong)	1.65-1.69	Tourmaline, chrysoberyl	Strong double refraction, low dichroism.
Quartz:										
Agate	Silicon dioxide	Any	Large	Low	7.0	2.58-2.64	XX	XX	Glass, plastic, Mexican onyx	Cryptocrystalline, irregularly banded, dendritic inclusions.

See footnotes at end of table.

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TABLE 1—Continued
GUIDE TO SELECTED GEMSTONES AND GEM MATERIALS USED IN JEWELRY

Name	Composition	Color	Practical size[1]	Cost[2]	Mohs	Specific gravity	Refraction	Refractive index	May be confused with	Recognition characteristics
Quartz—Continued:										
Amethyst	Silicon dioxide	Purple	Large	Medium	7.0	2.65-2.66	Double	1.55	Glass, plastic, fluorite	Macrocrystalline, color, refractive index, transparent, hardness.
Aventurine	do.	Green, red-brown, gold-brown, with metallic iridescent reflection	do.	Low	7.0	2.64-2.69	do.	1.54-1.55	Iridescent analcime, aventurine feldspar, emerald, aventurine glass	Macrocrystalline, color, metallic iridescent flake reflections, hardness.
Cairngorm	do.	Smoky orange or yellow	do.	do.	7.0	2.65-2.66	do.	1.55	do.	Macrocrystalline, color, refractive index, transparent, hardness.
Carnelian	do.	Flesh red to brown red	do.	do.	6.5-7.0	2.58-2.64	do.	1.53-1.54	Jasper	Cryptocrystalline, color, hardness.
Chalcedony	do.	Bluish, white, gray	do.	do.	6.5-7.0	2.58-2.64	do.	1.53-1.54	Tanzanite	Do.
Chrysoprase	do.	Green, apple-green	do.	do.	6.5-7.0	2.58-2.64	do.	1.53-1.54	Chrome chalcedony, jade, prase opal, prehnite, smithsonite, variscite, artifically colored green chalcedony	Do.
Citrine	Silica	Yellow	do.	do.	7.0	2.65-2.66	do.	1.55	do.	Macrocrystalline, color, refractive index, transparent, hardness.
Crystal:										
Rock	do.	Colorless	do.	do.	7.0	2.65-2.66	do.	1.55	Topaz, colorless sapphire	Do.
Jasper	do.	Any, striped, spotted, or sometimes uniform	do.	do.	7.0	2.58-2.66	XX	XX	do.	Cryptocrystalline, opaque, vitreous luster, hardness.
Onyx	do.	Many colors	do.	do.	7.0	2.58-2.64	XX	XX	do.	Cryptocrystalline, uniformly banded, hardness.
Petrified wood	do.	Brown, gray, red, yellow	do.	do.	6.5-7.0	2.58-2.91	Double	1.54	Agate, jasper	Color, hardness, wood grain.
Rose	do.	Pink, rose red	do.	do.	7.0	2.65-2.66	do.	1.55	do.	Macrocrystalline, color, refractive index, transparent, hardness.
Tiger's eye	do.	Golden yellow, brown, red, blue-black	do.	do.	6.5-7.0	2.58-2.64	XX	1.53-1.54	XX	Macrocrystalline, color, hardness, hatoyancy.

See footnotes at end of table.

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TABLE 1—Continued
GUIDE TO SELECTED GEMSTONES AND GEM MATERIALS USED IN JEWELRY

Name	Composition	Color	Practical size[1]	Cost[2]	Mohs	Specific gravity	Refraction	Refractive index	May be confused with	Recognition characteristics
Rhodochrosite	Manganese carbonate	Rose-red to yellowish, stripped	Large	Low	4.0	3.45-3.7	Double	1.6-1.82	Fire opal, rhodonite, tugtupite, tourmaline	Color, crystal habit, reaction to acid, perfect rhombohedral cleavage.
Rhodonite	Manganese iron calcium silicate	Dark red, flesh red, with dendritic inclusions of black manganese oxide	do.	do.	5.5-6.5	3.40-3.74	do.	1.72-1.75	Rhodochrosite, thulite, hessonite, spinel, pyroxmangite, spessartine, tourmaline	Color, black inclusions, lack of reaction to acid, hardness.
Shell:										
Mother-of-pearl	Calcium carbonate	White, cream, green, blue-green, with iridescent play of color	Small	do.	3.5	2.6-2.85	XX	XX	Glass and plastic imitation	Luster, iridescent play of color.
Pearl	do.	White, cream to black, sometimes with hint of pink, green, purple	do.	Low to high	2.5-4.5	2.6-2.85	XX	XX	Cultured and glass or plastic imitation	Luster, iridescence, x-structure, ray.
Spinel	Magnesium aluminum oxide	Any	Small to medium	Medium	8.0	3.5-3.7	Single	1.72	Synthetic, garnet	Refractive index, single refraction, inclusions.
Spinel, synthetic	do.	do.	Up to 40 carats	Low	8.0	3.5-3.7	Double	1.73	Spinel, corundum, beryl, topaz, alexandrite	Weak double refraction, curved striae, bubbles.
Spodumene:										
Hiddenite	Lithium aluminum silicate	Yellow to green	Medium	Medium	6.5-7.0	3.13-3.20	do.	1.66	Synthetic spinel	Refractive index, color, pleochroism.
Kunzite	do.	Pink to lilac	do.	do.	6.5-7.0	3.13-3.20	do.	1.66	Amethyst, morganite	Do.
Tanzanite	Complex silicate	Blue to lavender	Small	High	6.0-7.0	3.30	do.	1.69	Sapphire, synthetics	Strong trichroism, color.
Topaz	do.	White, blue, green, pink, yellow, gold	Medium	Low to medium	8.0	3.4-3.6	do.	1.62	Beryl, quartz	Color, density, hardness, refractive index, perfect in basal cleavage.
Tourmaline	do.	Any, including mixed	do.	do.	7.0-7.5	2.98-3.20	do.	1.63	Peridot, beryl, garnet corundum, glass	Double refraction, color, refractive index.
Turquoise	Copper aluminum phosphate	Blue to green with black, brown-red inclusions	Large	Low	6.0	2.60-2.83	do.	1.63	Chrysocolla, dyed howlite, dumortierite, glass, plastics, variscite	Difficult if matrix not present, matrix usually limonitic.
Unakite	Granitic rock, feldspar, epidote, quartz	Olive green, pink, and blue-gray	do.	do.	6.0-7.0	2.60-3.20	XX	XX	XX	Olive green, pink, gray-blue colors.
Zircon	Zirconium silicate	White, blue, brown, yellow, or green	Small to medium	Low to medium	6.0-7.5	4.0-4.8	Double (strong)	1.79-1.98	Diamond, synthetics, topaz, aquamarine	Double refraction, strongly dichroic, wear on facet edges.

XX Not applicable.

[1]Small: up to 5 carats; medium: 5 to 50 carats; large: more than 50 carats.

[2]Low: up to $25 per carat; medium: up to $200 per carat; high: more than $200 per carat.

[3]Commonwealth of Independent States.

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TABLE 2
LABORATORY-CREATED GEMSTONE PRODUCTION METHODS

Gemstone	Production method	Company/producer	Date of first production
Alexandrite	Flux	Creative Crystals	1970s.
Do.	Melt pulling	J.O. Crystal	1990s.
Do.	do.	Kyocera	1980s.
Do.	Zone melt	Seiko	1980s.
Cubic zirconia	Skull melt	Various producers	1970s.
Emerald	Flux	Chatham	1930s.
Do.	do.	Gilson	1960s.
Do.	do.	Kyocera	1970s.
Do.	do.	Seiko	1980s.
Do.	do.	Lennix	1980s.
Do.	do.	Russia	1980s.
Do.	Hydrothermal	Lechleitner	1960s.
Do.	do.	Regency	1980s.
Do.	do.	Biron	1980s.
Do.	do.	Russia	1980s.
Ruby	Flux	Chatham	1950s.
Do.	do.	Kashan	1960s.
Do.	do.	J.O. Crystal	1980s.
Do.	do.	Douras	1990s.
Do.	Zone melt	Seiko	1980s.
Do.	Melt pulling	Kyocera	1970s.
Do.	Verneuil	Various producers	1900s.
Sapphire	Flux	Chatham	1970s.
Do.	Zone melt	Seiko	1980s.
Do.	Melt pulling	Kyocera	1980s.
Do.	Verneuil	Various producers	1900s.
Star ruby	do.	Linde	1940s.
Do.	Melt pulling	Kyocera	1980s.
Do.	do.	Nakazumi	1980s.
Star sapphire	Verneuil	Linde	1940s.

TABLE 3
VALUE OF U.S. GEMSTONE PRODUCTION, BY TYPE[1]

(Thousand dollars)

Gem materials	2004	2005
Beryl	18	48
Coral, all types	261	216
Diamond	(2)	(2)
Garnet	207	46
Gem feldspar	659	626
Geode/nodules	212	214
Opal	137	140
Quartz:		
Macrocrystalline[3]	206	196
Cryptocrystalline[4]	383	427
Sapphire/ruby	473	450
Shell	4,000	3,560
Topaz	(2)	(2)
Tourmaline	45	39
Turquoise	699	511
Other	7,170 r	6,960
Total	14,500	13,400

See footnotes at end of table.

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TABLE 3—Continued
VALUE OF U.S. GEMSTONE PRODUCTION, BY TYPE[1]

[r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Included with "Other."
[3]Macrocrystalline quartz (crystals recognizable with the naked eye) includes amethyst, amethyst quartz, aventurine, blue quartz, citrine, hawk's eye, pasiolite, prase, quartz cat's eye, rock crystal, rose quartz, smoky quartz, and tiger's eye.
[4]Cryptocrystalline (microscopically small crystals) includes agate carnelian, chalcedony, chrysoprase, fossilized wood, heliotrope, jasper, moss agate, onyx, and sard.

TABLE 4
PRICES OF U.S. CUT DIAMONDS, BY SIZE AND QUALITY IN 2005[1]

Carat weight	Description, color[2]	Clarity[3] (GIA terms)	Representative prices January[4]	June[5]	December[6]
0.25	G	VS1	$1,200	$1,200	$1,200
do.	G	VS2	1,150	1,150	1,150
do.	G	SI1	975	975	975
do.	H	VS1	1,100	1,100	1,100
do.	H	VS2	1,000	1,000	1,000
do.	H	SI1	925	925	925
0.50	G	VS1	3,200	3,200	3,200
do.	G	VS2	2,800	2,800	2,800
do.	G	SI1	2,400	2,400	2,400
do.	H	VS1	2,800	2,800	2,800
do.	H	VS2	2,400	2,400	2,400
do.	H	SI1	2,200	2,200	2,200
0.75	G	VS1	3,600	3,600	3,600
do.	G	VS2	3,500	3,500	3,500
do.	G	SI1	3,200	3,200	3,200
do.	H	VS1	3,300	3,300	3,300
do.	H	VS2	3,200	3,200	3,200
do.	H	SI1	2,900	2,900	2,900
1.00	G	VS1	5,800	5,800	5,800
do.	G	VS2	5,500	5,500	5,500
do.	G	SI1	4,800	4,800	4,800
do.	H	VS1	5,200	5,200	5,200
do.	H	VS2	4,900	4,900	4,900
do.	H	SI1	4,700	4,700	4,700

[1]Data are rounded to no more than three significant digits.
[2]Gemological Institute of America (GIA) color grades: D—colorless; E—rare white; G, H, I—traces of color.
[3]Clarity: IF—no blemishes; VVS1—very, very slightly included; VS1—very slightly included; VS2—very slightly included, but not visible; SI1—slightly included.
[4]Source: Jewelers' Circular Keystone, v. 174, no. 2, February 2003, p. 44.
[5]Source: Jewelers' Circular Keystone, v. 174, no. 7, July 2003, p. 52.
[6]Source: Jewelers' Circular Keystone, v. 175, no. 1, January 2004, p. 28.

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TABLE 5
PRICES PER CARAT OF U.S. CUT COLORED GEMSTONES IN 2005

Gemstone	Price range per carat	
	January[1]	December[2]
Amethyst	$7-15	$7-15
Blue sapphire	625-1,250	625-1,250
Blue topaz	3-5	3-5
Emerald	1,900-3,200	1,900-3,200
Green tourmaline	45-60	45-60
Pearl:[3]		
Cultured saltwater	5	5
Natural	210	210
Pink tourmaline	60-125	60-125
Rhodolite garnet	18-30	18-30
Ruby	900-1,125	900-1,125
Tanzanite	250-375	250-400

[1]Source: The Guide, spring/summer 2005, p. 14, 30, 45, 61, 72, 86, 96, 98, 104, 123, and 135. These figures are approximate current wholesale purchase prices paid by retail jewelers on a per stone basis for fine-quality stones.

[2]Source: The Guide, fall/winter 2005-2006, p. 14, 30, 45, 61, 72, 86, 96, 98, 104, 123, and 135. These figures are approximate current wholesale purchase prices paid by retail jewelers on a per stone basis for fine-quality stones.

[3]Prices are per 4.6-millimeter pearl.

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TABLE 6
U.S. EXPORTS AND REEXPORTS OF DIAMOND (EXCLUSIVE OF INDUSTRIAL DIAMOND), BY COUNTRY[1]

	2004		2005	
Country	Quantity (carats)	Value[2] (millions)	Quantity (carats)	Value[2] (millions)
Exports:				
Australia	7,570	$7	33,700	$7
Belgium	189,000	100 r	1,300,000	538
Canada	68,500	47	84,200	56
Costa Rica	31,800	3	37,200	3
France	16,300	11	90,000	51
Hong Kong	529,000	219	1,030,000	294
India	151,000	31	206,000	57
Israel	352,000 r	208 r	1,890,000	1,090
Japan	22,600	26	52,400	53
Mexico	397,000	124	1,080,000	144
Netherlands	421	3	27,600	8
Netherlands Antilles	47,200	23	35,500	33
Singapore	12,300	5	54,000	19
South Africa	498	(3)	21,100	4
Switzerland	19,000 r	47	108,000	82
Taiwan	11,000	6	16,700	4
Thailand	68,500	15	98,000	28
United Arab Emirates	15,700	4	101,000	43
United Kingdom	26,300	28	78,800	22
Other	52,200 r	29 r	87,200	46
Total	2,020,000 r	936 r	6,430,000	2,580
Reexports:				
Armenia	69,500 r	3	44,300	3
Australia	19,100	7	40,300	8
Belgium	4,780,000 r	1,370 r	3,920,000	1,100
Canada	223,000 r	107 r	247,000	136
Dominican Republic	104,000	23	153,000	33
France	155,000	32 r	88,200	16
Guatemala	91,100	8	107,000	12
Hong Kong	2,690,000 r	490 r	2,500,000	618
India	2,200,000 r	345 r	1,840,000	387
Israel	7,650,000 r	2,690 r	7,670,000	2,640
Japan	207,000 r	47 r	150,000	33
Malaysia	41,100	9	34,900	5
Mexico	37,000	5	57,700	11
Singapore	264,000 r	46	218,000	35
South Africa	78,000 r	48 r	47,600	36
Switzerland	563,000 r	289 r	638,000	303
Thailand	285,000 r	70	290,000	83
United Arab Emirates	477,000 r	108 r	612,000	142
United Kingdom	490,000 r	171	540,000	211
Other	147,000 r	59 r	122,000	87
Total	20,600,000 r	5,930 r	19,300,000	5,890
Grand total	22,600,000 r	6,870 r	25,700,000	8,470

rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Customs value.
[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF DIAMOND, BY KIND, WEIGHT, AND COUNTRY[1]

Kind, range, and country of origin	2004 Quantity (carat)	2004 Value[2] (millions)	2005 Quantity (carat)	2005 Value[2] (millions)
Rough or uncut, natural:[3]				
Angola	6,590	$19	19,400	$57
Australia	12,200	8	62,400	8
Botswana	144,000	48	274,000	132
Brazil	9,530	8	24,600	2
Canada	36,500	38	57,600	62
Congo (Kinshasa)	20,900	17	44,300	116
Ghana	1,910	(4)	58,000	3
Guyana	157,000	16	68,400	8
India	34,500	3	29,200	(4)
Namibia	28,700	1	10,700	1
Russia	250,000	20	45,500	13
South Africa	430,000	508	347,000	413
Other	74,400 r	68 r	16,800	49
Total	1,210,000	753	1,060,000	864
Cut but unset, not more than 0.5 carat:				
Belgium	786,000	275	530,000	197
Canada	4,800	4	7,890	9
China	67,100	10	78,900	13
Dominican Republic	37,200	4	57,100	5
Hong Kong	200,000	43	228,000	58
India	9,720,000	1,770	8,780,000	1,820
Israel	969,000	477	843,000	425
Mauritius	1,890	4	10,400	15
Mexico	14,400	(4)	247,000	35
Singapore	9,460	2	6,180	2
South Africa	8,410	3	5,330	2
Switzerland	7,390	2	33,600	18
Thailand	189,000	36	71,500	18
United Arab Emirates	122,000	24	91,600	23
Other	67,700 r	15 r	28,600	13
Total	12,200,000	2,670	11,000,000	2,650
Cut but unset, more than 0.5 carat:				
Belgium	1,230,000	2,450	1,160,000	2,620
Canada	23,600	67	15,200	50
Hong Kong	71,300	111	83,400	162
India	1,530,000	1,080	1,340,000	1,260
Israel	3,080,000	6,660	3,070,000	7,670
Mexico	16	(4)	49,900	37
Russia	62,200	121	57,600	126
South Africa	40,500	242	46,300	336
Switzerland	20,100	155	16,600	138
Thailand	21,300	23	21,200	20
United Arab Emirates	23,800	21	50,300	64
Other	88,200 r	272 r	67,000	235
Total	6,190,000	11,200	5,980,000	12,700

rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Customs value.

[3]Includes some natural advanced diamond.

[4]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES, OTHER THAN DIAMOND, BY KIND AND COUNTRY[1]

Kind and country	2004 Quantity (carats)	2004 Value[2] (millions)	2005 Quantity (carats)	2005 Value[2] (millions)
Emerald:				
Argentina	--	--	12,500	(3)
Belgium	25,200	$2	4,230	$1
Brazil	355,000	4	83,600	5
Canada	412	(3)	6,430	(3)
China	227,000	1	17,900	(3)
Colombia	677,000	47	456,000	54
France	745	1	2,360	7
Germany	7,440	1	93,600	1
Hong Kong	57,100	4	86,100	8
India	1,880,000	18	1,340,000	17
Israel	259,000	21	139,000	22
Italy	865	(3)	3,120	2
Namibia	--	--	4,590	(3)
Switzerland	9,450	7	18,500	8
Thailand	424,000	8	348,000	7
United Kingdom	851	2	2,520	2
Other	74,600	6	4,770	2
Total	4,000,000	122	2,620,000	137
Ruby:				
Belgium	6,450	2	11,600	1
China	21,700	(3)	29,700	(3)
Dominican Republic	4,920	(3)	23,600	(3)
France	786	1	2,300	5
Germany	19,400	1	77,600	1
Hong Kong	52,100	4	119,000	7
India	1,300,000	4	935,000	5
Israel	41,300	1	8,840	1
Italy	6,570	(3)	4,340	1
Kenya	526	(3)	33,500	(3)
Sri Lanka	5,260	1	4,080	1
Switzerland	2,230	11	89,300	29
Thailand	2,090,000	43	3,030,000	48
United Arab Emirates	7,700	1	3,340	1
Other	186,000	2	8,630	2
Total	3,750,000	72	4,380,000	102
Sapphire:				
Australia	5,300	(3)	57,900	1
Austria	947	(3)	29,600	1
Belgium	4,480	1	7,120	1
China	120,000	(3)	84,100	(3)
Dominican Republic	3,750	(3)	24,500	(3)
Germany	41,000	2	72,700	5
Hong Kong	138,000	7	272,000	15
India	1,040,000	9	987,000	6
Israel	56,600	3	31,600	3
Italy	4,130	(3)	5,880	(3)
Singapore	379	(3)	5,350	(3)
Sri Lanka	455,000	42	448,000	45
Switzerland	29,900	11	49,000	9
Thailand	5,470,000	78	5,620,000	81

See footnotes at end of table.

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TABLE 8—Continued
U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES, OTHER THAN DIAMOND, BY KIND AND COUNTRY[1]

Kind and country	2004 Quantity (carats)	2004 Value[2] (millions)	2005 Quantity (carats)	2005 Value[2] (millions)
Sapphire—Continued:				
United Arab Emirates	7,360	(3)	2,490	(3)
United Kingdom	7,820	$3	2,550	(3)
Other	113,000	4	14,700	$5
Total	7,500,000	163	7,710,000	174
Other:				
Rough, uncut:				
Australia	NA	3	NA	2
Brazil	NA	8	NA	10
Canada	NA	3	NA	4
China	NA	3	NA	4
Colombia	NA	1	NA	1
Czech Republic	NA	(3)	NA	2
Germany	NA	2	NA	3
India	NA	1	NA	1
Japan	NA	(3)	NA	1
Mexico	NA	1	NA	1
Netherlands	NA	1	NA	1
Pakistan	NA	1	NA	1
South Africa	NA	7	NA	1
Tanzania	NA	1	NA	3
United Kingdom	NA	(3)	NA	1
Other	NA	5 r	NA	5
Total	NA	39	NA	40
Cut, set and unset:				
Australia	NA	9	NA	9
Austria	NA	3	NA	4
Brazil	NA	13	NA	18
Canada	NA	1	NA	1
China	NA	45	NA	57
France	NA	1	NA	3
Germany	NA	38	NA	33
Hong Kong	NA	35	NA	49
India	NA	82	NA	93
Israel	NA	4	NA	5
Italy	NA	1	NA	1
South Africa	NA	5	NA	3
Sri Lanka	NA	7	NA	7
Switzerland	NA	10	NA	19
Taiwan	NA	2	NA	2
Tanzania	NA	7	NA	7
Thailand	NA	46	NA	40
United Arab Emirates	NA	2	NA	1
United Kingdom	NA	1	NA	1
Other	NA	7 r	NA	7
Total	NA	320	NA	360

rRevised. NA Not available. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Customs value.
[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 9
VALUE OF U.S. IMPORTS OF LABORATORY-CREATED AND IMITATION GEMSTONES, BY COUNTRY[1,2]

(Thousand dollars)

Country	2004	2005
Laboratory-created, cut but unset:		
Austria	2,410	3,700
Brazil	225	151
Canada	98	133
China	14,100	15,200
Cyprus	246	86
Czech Republic	114	91
France	989	945
Germany	13,800	12,200
Hong Kong	1,500	1,580
India	261	526
Ireland	7	69
Italy	75	131
Japan	112	110
Korea, Republic of	649	468
Netherlands	232	296
South Africa	--	87
Sri Lanka	1,290	1,300
Switzerland	3,340	2,050
Taiwan	197	238
Thailand	1,090	1,420
United Arab Emirates	--	70
Other	158 r	253
Total	40,900	41,100
Imitation:[3]		
Austria	60,800	73,600
Brazil	8	16
China	4,660	3,500
Czech Republic	7,000	11,000
France	16	13
Germany	974	1,160
Hong Kong	700	271
India	207	361
Italy	100	222
Japan	1,110	474
Korea, Republic of	774	619
Philippines	16	15
Russia	53	17
Spain	165	256
Taiwan	220	179
Thailand	31	52
United Kingdom	--	24
Other	227 r	109
Total	77,000	91,900

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Customs value.

[3]Includes pearls.

Source: U.S. Census Bureau.

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TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF GEMSTONES[1]

(Thousand carats and thousand dollars)

Stones	2004		2005	
	Quantity	Value[2]	Quantity	Value[2]
Diamonds:				
Rough or uncut	1,210	753,000	1,060	864,000
Cut but unset	18,400	13,900,000	17,000	15,400,000
Emeralds, cut but unset	4,000	122,000	2,630	137,000
Coral and similar materials, unworked	6,120	11,500	5,520	12,200
Rubies and sapphires, cut but unset	11,200	234,000	12,100	275,000
Pearls:				
Natural	NA	15,500 r	NA	21,800
Cultured	NA	29,500	NA	27,100
Imitation	NA	3,780	NA	4,170
Other precious and semiprecious stones:				
Rough, uncut	1,130,000	25,200	1,630,000	22,900
Cut, set and unset	NA	279,000	NA	319,000
Other	NA	5,680	NA	7,200
Laboratory-created:				
Cut but unset	249,000	40,900	196,000	41,100
Other	NA	8,110	NA	10,300
Imitation gemstone[3]	NA	73,300	NA	87,700
Total	XX	15,500,000 r	XX	17,200,000

rRevised. NA Not available. XX Not applicable.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Customs value.

[3]Does not include pearls.

Source: U.S. Census Bureau.

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TABLE 11

NATURAL DIAMOND: WORLD PRODUCTION, BY COUNTRY AND TYPE[1, 2, 3]

(Thousand carats)

Country and type[4]	2001	2002	2003	2004	2005
Gemstones:					
Angola[e]	4,643 r	4,520	5,130 r	5,490 r	5,580
Australia	14,397 r	15,136 r	13,981 r	20,602 r	20,000 e
Botswana[e]	19,812 r, 5	21,297 r, 5	22,800	23,300	23,900
Brazil[e]	700	500 5	400 r	300 r, 5	300
Canada	3,716	4,937	10,756 r	12,618	12,300
Central African Republic[e]	340	312	250	263 r	265
China[e]	100 r	100 r	100 r	100 r	100
Congo (Kinshasa)	3,638	4,223 r	5,381 r	6,180 r	6,300 e
Côte d'Ivoire	207 e	205 r	154 r	201 r, e	201 e
Ghana	936 e	770 e	675 r	690 r	760 e
Guinea[e]	273	368	484 6	354 r, 6	411 6
Guyana	179	248	413	455 r	357
Liberia[e]	100	48	36	18	18
Namibia	1,487	1,562	1,481	2,004 r	1,900 e
Russia[e]	17,500	17,400	20,000	21,400	23,000
Sierra Leone	102 r	162 r	233 r, e	318 r, e	318 e
South Africa	4,465 r	4,351 r	5,144 r	5,780 e	5,780 e
Tanzania[e]	216 5	204	201	258 r	175
Venezuela	14	46	11	40 e	46 e
Other[7]	54 r	42 r	44 r	74 r	110
Total	72,900 r	76,400 r	87,700 r	100,000 r	102,000
Industrial:					
Angola[e]	516	502	570 r	610 r	620
Australia	11,779 r	18,500	17,087 r	22,709 r	20,000 e
Botswana[e]	6,604 r, 5	7,100	7,600	7,800	8,000
Brazil[e]	600	600	600	600	600
Central African Republic[e]	113	104	83	88 r	88
China[e]	950	955	955	960	960
Congo (Kinshasa)	14,560	17,456	21,600	24,700 r	25,200 e
Côte d'Ivoire	102	101 r	76 r	99 r, e	99 e
Ghana[e]	234	193	225 r	230 r	253
Guinea[e]	91	123	161 6	118 r, 6	137 6
Liberia[e]	70	32	24	12	12
Russia[e]	11,700	11,600	13,000	14,200	15,000
Sierra Leone	120 r	190 r	274 r, e	374 r, e	374 e
South Africa	6,698 r	6,526 r	7,540 r	8,500 r, e	9,380 e
Tanzania	38	36	36	46 r	30
Venezuela	28	61	24	60 e	69 e
Other[8]	91 r	81 r	82 r	121 r	190
Total	54,300 r	64,200 r	69,900 r	81,200 r	81,000
Grand total	127,000	141,000 r	158,000 r	182,000 r	183,000

[e]Estimated. [r]Revised.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 5, 2006.

[3]In addition to the countries listed, Nigeria produces natural diamond, but information is inadequate to formulate reliable estimates of output levels.

[4]Includes near-gem and cheap-gem qualities.

[5]Reported figure.

[6]Exports.

[7]Includes Cameroon, Congo (Brazzaville), Gabon (unspecified), India, Indonesia, and Zimbabwe.

[8]Includes Congo (Brazzaville), India, Indonesia, and Zimbabwe.

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GERMANIUM

By Xiaoyu Bi

Domestic survey data and table were prepared by Maria Arguelles, statistical assistant.

In 2005, germanium was produced at two refineries and recovered from zinc concentrates produced at two zinc mines in the United States. The two domestic zinc-mining operations in Alaska and Washington produced germanium-containing zinc concentrates that were exported to Canada for processing. Another zinc mine that had produced germanium-rich zinc concentrates in Tennessee closed in May 2003.

The U.S. Geological Survey (USGS) estimated domestic germanium reserves, factored from zinc reserves, to be 450,000 kilograms (kg). Data for worldwide reserves were not available. Worldwide germanium resources were associated with zinc and lead-zinc-copper sulfide ores. Germanium was also recovered to a lesser extent from coal ash and cobalt-copper ores.

Germanium is a hard, brittle semimetal that first was used about one-half century ago as a semiconductor material in radar units and as the material for the first transistors. Today, it is used principally as a polymerization catalyst for polyethylene terephthalate (PET), a commercially important plastic; a component of glass in telecommunications fiber optics; in infrared night-vision devices; and as a semiconductor and substrate in electronics circuitry.

Legislation and Government Programs

As a strategic and critical material, germanium was included in the National Defense Stockpile (NDS) in 1984. All the material purchased for the stockpile was zone-refined polycrystalline germanium metal.

According to the Defense Logistics Agency (DLA), sales began 2005 at $605 per kilogram and ended the year at $676 per kilogram. The DLA reported that sales for calendar year 2005 were 4,512 kg compared with 7,186 kg in 2004 and that, as of December 31, 2005, the NDS inventory of germanium metal was 28,851 kg, all of which has been authorized for sale. Germanium was offered for sale on the fourth Monday of each month, and the DLA was authorized to sell up to 8,000 kg during fiscal year 2006 (Defense Logistics Agency, 2005).

Production

Domestic refinery production for germanium was estimated by the USGS based on data provided by North American producers. The USGS estimated that U.S. refinery production of germanium from fly ash, imported primary material and germanium compounds, and new scrap increased in 2005 to 4,500 kg from 4,400 kg in 2004. Production of refined germanium in 2004 and preceding years was revised significantly downward to avoid counting material imported in chemical form and directly consumed or consumed in the production of other germanium compounds.

In July 2003, Umicore Optical Materials USA Inc. (a subsidiary of Umicore NV/SA, Brussels, Belgium) acquired certain assets of EaglePicher Technologies' germanium operations based in Quapaw, OK, which remained the leading domestic producer of germanium in 2005. Umicore produced germanium from fly ash, germanium concentrates (typically containing 5% germanium or more), scrap, and imported germanium compounds. About 10% of Umicore's germanium and cobalt was produced from scrap. This facility also produced germanium-base products used in fiber-optics, infrared devices, and substrates for electronic devices (Umicore NV/SA, 2006, p. 13).

Germanium Corporation of America (a subsidiary of Indium Corporation of America) produced germanium products including germanium tetrachloride, germanium dioxide, and germanium metal at its facility in Utica, NY.

Teck Cominco Limited produced germanium-containing zinc concentrates at its Red Dog zinc-lead open pit mine in Alaska and its Pend Oreille zinc-lead underground mine in Washington State. Concentrates produced at the Red Dog and Pend Oreille Mines were shipped to the company's metallurgical complex in Trail, British Columbia, Canada, where the zinc concentrates were treated in roasters or pressure leach facilities to extract germanium coproducts. Approximately 25% of the zinc concentrate produced at Red Dog was shipped to the Trail facility (Teck Cominco Limited, 2006, p. 8).

Consumption

The USGS estimated that domestic consumption of germanium increased to 27,000 kg in 2005 from 25,000 kg in 2004. Worldwide, the end-use pattern was estimated to be as follows: catalysts for PET, 31%; fiber optics, 24%; infrared optics, 23%; electrical/solar applications, 12%; and other uses (such as phosphors, metallurgy, and chemotherapy), 10%. The domestic end-use pattern was significantly different, however, with fiber optics accounting for 40%; infrared optics, 30%; electronics/solar electrical applications, 20%; and other uses (phosphors, metallurgy, and chemotherapy), 10%. Germanium was not used in PET catalysts in the United States.

In the fiber optics sector, germanium was used as a dopant (a substance added in small amounts to the pure silica glass core to increase its refractive index while not absorbing light) within the core of optical fibers used by the telecommunications industry.

Germanium lenses and windows are transparent to infrared radiation, which allows them to be used in infrared optical systems in the same way that ordinary glass lenses and windows are used in visible-light optical systems. These germanium-base optical systems have been used principally for military guidance and weapon-sighting applications, including satellite systems and personnel detection equipment for poor visibility environments. Germanium optical glass also is used for

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nonmilitary purposes in monitoring systems, night-vision applications for luxury vehicles, and surveillance equipment.

In the polymerization catalysts sector outside the United States, germanium consumption as a catalyst for PET production has remained stable.

Germanium-base devices have become well established for analog and digital functions. Silicon germanium (SiGe) enables manufacturers to produce smaller transistors with less electronic noise interference. Germanium-base transistors, referred to also as chips, are more energy efficient than traditional silicon-base chips, extending the life of the battery in wireless devices. Other benefits include more stability over a wider range of temperatures and the ability to operate at ultrahigh frequencies (IBM Research, 2004§[1]).

Prices

Free market prices for germanium dioxide, published by Metal Bulletin, remained in the range of $360 to $430 per kilogram during 2005. Based on NDS sales, the price of zone-refined metal averaged $621.39 per kilogram during 2005 (Defense Logistics Agency, 2005§).

Trade

The U.S. Census Bureau (2006§) reported that imports of germanium (wrought, unwrought, and waste and scrap material) increased to approximately 16,700 kg in 2005 from 9,130 kg in 2004. Belgium, China, Germany, and Russia, in descending order of quantity, accounted for 95% of imports into the United States in 2005 (table 1). In addition, the estimated germanium content of the germanium dioxide imported in 2005 was 11,800 kg, compared with 15,200 kg in 2004. When metal imports and estimated metal content of germanium dioxide imports are added together, Belgium accounted for 49.5%; Canada, 20.9%; China, 11.5%; Germany, 11.2%; and Russia, 6.10% of imports of contained germanium metal into the United States.

Exports of germanium and articles thereof, including waste and scrap, were 10,100 kg in 2005 according to the U.S. Census Bureau. Low-value waste exported to Belgium accounted for about 90% of exports of germanium from the United States in 2005. The estimated germanium content of germanium dioxide exported in 2005 was 732 kg. When metal exports and estimated metal content of germanium dioxide exports were added together, Belgium was the destination for 88.5%; Canada, 4.8%; Germany, 1.9%; Russia, 1.5%; and China, 1.4% of exports of contained germanium metal from the United States.

World Industry Structure

In 2005, the world's total estimated supply of germanium was 90 metric tons (t), including 4,500 kg released from the NDS. The recycling level remained about the same and supplied about 31 t of the world's total supply of germanium.

[1]References that include a section mark (§) are found in the Internet References Cited section.

Starting in 2001 and continuing through 2002, there had been a growing surplus of germanium owing to a major downturn in the fiber optics market. The bottom of this recent cycle was in 2003, and by yearend 2003, supply and demand were in close balance. Lower production and moderate demand growth resulted in a tight supply in 2004. In 2005, the germanium market remained tight with little change in supply and demand (Metal-Pages, 2005a§).

Current Research and Technology

Germanium continued to be used for thermal imaging in night-vision systems. The germanium lens focuses the infrared (IR) rays from the observed object to a detector. Umicore introduced germanium arsenic selenium IR (GASIR), a new material used in the far-infrared night vision system produced by Autoliv Inc., a German automotive safety equipment manufacturer. GASIR lenses have excellent IR transmission properties while containing only 20% germanium. Also, through an efficient molding technique, Umicore was able to minimize waste production and reduce production costs. IR radiation can be transmitted through the GASIR lens system from up to 300 meters away (Umicore NV/SA, 2006, p. 16).

Consumer demand for night-vision systems in automobiles dropped in 2004, prompting General Motors Corp. (GM) to drop the option from its 2006 model Cadillac vehicles. GM continued to offer night-vision as a dealer-installed option in its Hummer models. Toyota Motor Corporation reported that the percentage of Lexus models sold with night-vision fell to less than 5% by yearend from 26% in early 2004 (Business Week, 2004§).

In August, IBM announced that it had developed the 130-nanometer SiGe bipolar complementary metal oxide semiconductor (BiCMOS) technology, allowing for higher performance and efficiency in wireless applications than the prior SiGe technology. Some of the products that can be integrated with this new technology include safety systems for automobiles (blindside detection and collision warning), 60-gigahertz (GHz) Wi-Fi chips, software defined radios for cellular devices, and high-speed analog-to-digital (A/D) and digital-to-analog (D/A) converters (IBM Corp., 2005§).

Research conducted by the Georgia Tech Research Institute through its Silicon-Germanium Transmit-Receive Module Project was aimed at developing SiGe technology for future phased-array radar systems. Researchers were investigating SiGe chips that are less expensive and hold a significantly larger number of high-speed circuits on a single chip than do gallium arsenide or indium phosphide compound semiconductors. SiGe technology generates much less radio frequency (RF) power than gallium arsenide devices, making SiGe amplifiers a better match for radar compared with other applications that require more power output (Georgia Institute of Technology, 2005§).

A new tarnish-resistant sterling silver alloy was developed that contained about 1.2% germanium. Any tarnish that develops on the alloy can easily be removed with a wet sponge. The alloy is free from firescale when heated, eliminating the need to strip off oxidation with hazardous chemicals. It is also stronger and more dent-resistant, allowing for larger silver designs (Silver Institute, The, 2005§).

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Researchers at Riken Corp., one of Japan's leading institutes for science and technology, have developed a new product that exhibits negative thermal expansion with higher electric and thermal conductivities than other metals. Negative thermal expansion allows the product to shrink significantly with rising temperature. The properties of the product are the result of replacing select zinc and gallium atoms with germanium in an anti-perovskite-structure manganese nitride (Mn3XN). Possible applications are in precision devices and components that have to avoid any thermal expansion (Metal-Pages, 2005b§).

Outlook

Nearing the end of 2005, hazardous environmental conditions forced more than a dozen zinc smelters in China to shut down; however, this did not disrupt the germanium market (Metal-Pages, 2005c§). Zinc mine closures in Australia, Canada, and the United States and smelting facilities closures in Europe have lowered the output of byproduct germanium. However, germanium production capacity and the availability of primary and secondary material are projected to be sufficient to overcome a near-term deficit of germanium metal (Wilson, 2005).

Higher recycling rates of PET catalyst material and replacements of germanium as a catalyst in PET plastics manufacturing will erode the consumption of germanium in Asia. Titanium-base catalyst for PET production was preferred over antimony, germanium, and other rare earth metals owing to the availability and lower cost of titanium (Metal-Pages, 2005d§).

Reduced catalyst demand in Asia could be partially offset by domestic growth in optical fiber production. A continued recovery in the telecommunications sector as phone and cable companies improve access to metropolitan areas, the new innovation fiber-to-home, and an upgrading of telecommunications networks in Asia could mean a strong surge in demand for germanium along with continued increase in fiber optics use. The use of germanium was expected to continue to increase moderately along with the growth of new services in the telecommunications market. Growing industry segments [such as voice over internet protocol (VoIP), streaming media, and wireless networking (Wi-Fi)], and fiber-optic innovations have increased demand. Fiber-optic use in the Far East has been predicted to increase.

Another growth area is in the IR optics area owing to increased interest for IR devices by the military, in security and surveillance equipment, and the automobile market. Germanium consumption in the thin-film application for DVDs, germanium-base semiconductors, and other electronic uses for germanium also show growth potential.

SiGe technology could launch more affordable systems for communication, aircraft weather radar, and mobile uses for electronic system developments, such as those used in space programs.

In addition, germanium substrates for solar electronic applications are expected to increase in the short term because of increased demand for satellite communication. Overall, the demand for germanium is expected to moderately increase in conjunction with a tightening supply.

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TABLE 1

U.S. IMPORTS OF GERMANIUM, BY CLASS AND COUNTRY[1, 2]

Class and country	2004		2005	
	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Wrought, unwrought, waste, and scrap:				
Belgium	2,710	$2,850,000	9,060	$4,930,000
Canada	521	335,000	282	191,000
China	2,660	1,520,000	3,110	2,080,000
Germany	1,140	1,130,000	2,300	2,350,000
Hong Kong	50	30,600	--	--
India	--	--	184	134,000
Israel	66	61,800	16	17,700
Japan	--	--	45	32,100
Russia	1,950	1,310,000	1,740	1,490,000
Switzerland	9	2,350	--	--
United Kingdom	25	19,400	1	5,810
Total	9,130	7,260,000	16,700	11,200,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Does not include germanium dioxide imports.

Source: U.S. Census Bureau.

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GOLD

By Micheal W. George

Domestic survey data and tables were prepared by Mahbood Mahdavi and Wanda G. Wooten, statistical assistants, and the world production table was prepared by Regina R. Coleman, international data coordinator.

In 2005, domestic mine production of gold fell to 256,000 kilograms (kg), slightly down compared with that of 2004 (table 2). The reduction was a result of closure of one mine in Washington and lower output from older mines. The recent price increases have spurred exploration and development of new gold projects. However, since new mines take years to open, there was a lag in new mines to open to replace older mines. Stronger global gold prices offset the reduction in gold production, resulting in an increase in gold value for 2005 by 8% compared with that of 2004. The United States remained the world's third ranked gold producer, behind South Africa and Australia. Nevada accounted for almost 83% of domestic production in 2005. The remaining output came from Utah, Alaska, Colorado, Montana, Washington, South Dakota, California, New Mexico, Arizona, and Idaho, in descending order. Gold was produced at lode mines, a dozen large placer mines in Alaska, and numerous small placer mines, mostly in Alaska and the Western States. In addition, a small amount of domestic gold was produced as a byproduct of processing base metals, principally copper. In the United States, 30 mines yielded 99% of gold produced.

The 2005 domestic exploration budget increased to $396 million, a 39% increase compared with that of 2004. Much of the increase in exploration was caused by the increase in exploration in Alaska and Nevada and was concentrated on gold projects. Worldwide gold exploration expenditures rose by 28% compared with those of 2004 to $2.3 billion and represented 47% of the worldwide exploration budget for all minerals (Lowery, 2005; Wilburn, 2006).

Commercial-grade refined gold came from about two dozen domestic producers. Of several thousand companies and artisans, a few dozen companies dominated the fabrication of gold into commercial products. U.S. jewelry manufacturing was heavily concentrated in the New York City, NY, and Providence, RI, areas, with other manufacturers in California, Florida, and Texas. In 2005, the estimated percentages for end use of gold were jewelry and arts, 84%; dental and other, 10%; and electrical and electronics, 6%.

Trade in refined bullion comprised 31% of U.S. gold imports and 56% of exports; the United States became a net exporter of 76,300 kg bullion in 2005. Canada provided almost 59% of the refined bullion imported, and the United Kingdom and Switzerland were the destinations for 35% and 32%, respectively, of the refined bullion exported (tables 4, 6).

The dollar price for gold rose throughout 2005; however, the increase was less than in the previous 3 years. Engelhard Corp.'s daily price of gold ranged from a low of nearly $412 per troy ounce on February 8 to a high of about $538 per troy ounce on December 12. The average annual price of $446.20 per troy ounce, 9% above the average gold price in 2004, was the highest average annual price since 1987.

In 2005, there were five gold exchange traded funds (ETFs)—the two Gold Bullion Securities listed on the Australian and London [United Kingdom] Stock Exchanges, iShares COMEX Gold Trust, NewGold Gold Debentures listed on the Johannesburg [South Africa] Stock Exchange, and streetTRACKS gold shares, listed on the New York Stock Exchange. In 2005, gold in global ETFs increased by 203 metric tons (t). In total, the gold in ETFs in the United States increased by 190 t, with streetTRACKS accounting for 168 t of the increase, and iShares accounting for 22 t. Gold ETFs are essentially paper gold products, with each share representing a physical allotment of gold that is held in trust. Gold ETFs follow the gold prices, with a fee structure to cover administrative and storage costs. ETFs provided an easily accessible investment (Klapwijk and others, 2006, p. 26).

Total world mine production of gold was about 1% higher than that of 2004. South Africa decreased its annual output for the third year in a row because of higher costs and lower rand-based gold prices; however, South Africa remained the leading producer among more than 80 gold-mining nations, followed by Australia, the United States, China, and Peru (table 8).

Barrick Gold Corporation (Toronto, Ontario, Canada) agreed to acquire Placer Dome Inc. (Vancouver, British Columbia, Canada) to become the world's leading gold producer with an estimated annual production of 261,000 kg (reported as 8.4 million troy ounces) of gold, or 8% of the world's gold production (Austen, 2005; Barrick Gold Corporation, 2006, p. 2). The new company will control 6 of the 20 leading domestic gold mines, or 40% of domestic gold production (table 3).

It is estimated that 15% of all gold ever mined was employed in dissipative industrial uses or was unaccounted for or unrecoverable (Thomas and Boyle, 1986, p. 6). Therefore, of an estimated 151,000 t of gold mined historically through 2005, 128,000 t of gold remains in circulation, with 29,000 t held by central banks as official stocks and 99,000 t held privately as bullion, coin, and jewelry.

Production

In this report, domestic lode mine production data for gold were derived by the U.S. Geological Survey from two separate voluntary surveys of U.S. operations—one for monthly production of copper, gold, lead, silver, and zinc from lode mines and the other for production data surveyed annually. In 2005, one respondent reported that its mine closed. Individual company production and performance data listed in table 3 and cited elsewhere in this report were obtained from published sources, such as company annual reports. For purposes of ranking in this report, Newmont Mining Corporation's (Denver, CO) eastern Nevada mines are treated as a single operation.

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Alaska.—The State's Division of Geology and Geophysical Surveys reported that gold output decreased to 13,200 kg (reported as 423,000 troy ounces) worth $188 million in 2005 from 14,200 kg (reported as 457,000 troy ounces) worth $192 million in 2004, or a decrease in production of 7% and a decrease in value of 2%. Placer production, which is included in the numbers above, fell to 658 kg (reported as 21,200 troy ounces) from 767 kg (reported as 24,700 troy ounces) of gold (Szumigala and Hughes, 2006, p. 15).

The underground Fort Knox gold mine operated by Kinross Fairbanks Gold Mining Incorporated near Fairbanks began to produce gold in 1997. The mine produced about 10,200 kg (reported as 329,000 troy ounces) of gold in 2005, making it the country's ninth ranked gold mine (Kinross Gold Corporation, 2006, p. 13). The Greens Creek Mine on Admiralty Island near Juneau completed its ninth year at full production. Ore from the underground trackless mine was milled at the mine site. The smelter produced gold and silver dore, lead, zinc, and bulk concentrates. Hecla Mining Company reported that the mine produced 2,270 kg (reported as 72,800 troy ounces) of gold in 2005. Greens Creek is a joint venture between Kennecott Greens Creek Mining Co. (70.27%) and Hecla Mining Company (29.73%) (Hecla Mining Company, 2006, p. 6).

Coeur d'Alene Mines Corp. (Coeur d'Alene, ID), the world's leading silver producer, had received the final supplemental environmental impact statement and record of decision from the U.S. Forest Service in 2004 for the underground Kensington gold project, located 72 kilometers (km) north of Juneau. However, construction was delayed by lawsuits. All permits have since been obtained, construction commenced, and the mine was projected to begin production by yearend 2007, once the final lawsuit has been resolved. The project has an estimated 31,000 kg (reported as 1,050 thousand troy ounces) of gold reserves (Coeur d'Alene Mines Corp, 2006, p. 5).

In 2005, there were 16 exploration projects that had a budget of $1 million or greater. Northern Dynasty Minerals Ltd.'s (Vancouver, British Columbia, Canada) Pebble property near Iliamma was estimated to have 1,700 t (reported as 54.8 million troy ounces) of gold resources (Szumigala and Hughes, 2006, p. 2-3).

Arizona.—American Bonanza Gold Corp. (Vancouver) announced a preliminary resource estimate of more than 10,000 kg of gold in the Copperstone underground gold project in La Paz County (American Bonanza Gold Corp., 2006).

California.—California had four gold producing mines in 2005. These were, in decreasing order of gold production, Western Gold Fields Inc.'s Mesquite Mine, Glamis Rand Mining Co.'s Rand Mine, Canyon Resources Corp.'s Briggs Mine, and Quest Capital Corp.'s and MK Resources Co.'s joint-venture Castle Mountain Mine. These mines had ceased operations but were still processing stockpiled ore and mine waste in 2005.

Two of the four mines in California may restart in 2006. Western Gold Fields Inc. announced plans to resume open pit mining at its Mesquite Mine in an expanded area and explore high-grade ore extensions at depth. There are plans to also re-treat the existing heaps for additional gold recovery. Canyon Resources began an exploration study to determine the feasibility of restarting the Briggs Mine, which ceased mining in April 2004. The other two mines are under reclamation and there are no plans to restart them (Kohler, 2006).

Sutter Gold Mining Inc. (Riverton, WY) announced that it received the wastewater-discharge permit from the California Regional Water Quality Control Board in October for the Sutter gold project. The proposed underground gold mine includes the historic Lincoln Gold Mine located along California's Mother Load belt. Idaho Maryland Mine Corporation (Grass Valley, CA) submitted a mining permit application in October to re-open the historic Idaho Maryland Gold Mine. This project is still in the early phases of permitting, and the earliest it could open is late 2007. Other operations produced gold as a secondary product in 2005, mainly from alluvial sand and gravel mines and several small underground mines that primarily produced specimen gold products (Kohler, 2006).

Colorado.—Colorado was the fourth ranked gold-producing state in the country, according to the Colorado Geological Survey, producing 11,000 kg in 2005 (Keller and others, 2006). The Nation's eighth ranked gold mine, the Cresson Mine [owned by Cripple Creek & Victor Gold Mining Company (CC&V), to which AngloGold Ashanti Limited holds a 67%] reported that its open pit operation produced 10,300 kg of gold in 2005, up slightly compared with that of 2004 (AngloGold Ashanti Limited, 2006, p. 46). LKA International, Inc's Golden Wonder Mine in the San Juan Mountains produced 794 kg of gold in 2005, a 78% increase compared with that of 2004. The small, high-grade underground mine near Lake City began its operations in 1998. LKA announced plans to permit and develop a new section of the mine, which could significantly increase the production level. Calais Resources Ltd. continued work on its Consolidated Caribou project located within the northeast-trending Colorado mineral belt (Keller and others, 2006).

Idaho.—Although Idaho had limited gold production in 2005, several new mines were in various stages of development. New Jersey Mining Company (Kellogg, ID) had no less than six projects in development in 2005. Many of these were silver or gold-silver deposits in the Coeur d'Alene region in northern Idaho. Aside from New Jersey Mining, there were eight other companies with gold projects in early development stages in 2005 (Gillerman and others, 2006).

Montana.—Apollo Gold Corporation (Greenwood Village, CO) briefly resumed production at its Montana Tunnels Mine near Helena and produced 1,390 kg (reported as 44,100 troy ounces) of gold in 2005. Open pit mining activity was suspended on October 21 owing to pit stability issues. Apollo announced plans to sell Montana Tunnels in order to focus on the Black Fox project in Ontario, Canada, and the Huizopa project in Chihuahua, Mexico (Apollo Gold Corporation, 2006, p. 1-8).

Production at Placer Dome Inc.'s Golden Sunlight Mine was resumed in early 2005. The company announced plans to open the underground mine in 2006 and mine from both the open pit and underground for 3 years (McCulloch, 2005).

Nevada.—Gold production fell slightly to 212,000 kg, but Nevada still kept its longstanding position as the Nation's dominant gold-producing State and trailed only South Africa and Australia when compared with world production figures in 2005. Of the Nation's top 30 gold-producing mines, more than one-half were in Nevada.

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Newmont produced 71,500 kg (reported as 2.3 million troy ounces) of gold from 12 open pit operations and 5 underground mines in Elko, Eureka, Humboldt, and Lander Counties (Driesner and Coyner, 2006, p. 5-12).

Newmont has two new gold projects that began operations in 2005. The Phoenix project in Lander County began processing ore and could have the potential to produce 11,000 to 13,000 kilograms per year (kg/yr) (reported as 350,000 to 420,000 troy ounces per year) of gold. The Leeville project in Eureka County produced 497 kg (reported as 16,000 troy ounces) in 2005 and has an estimated full production of 17,300 kg/yr (reported as 555,000 troy ounces per year) (Newmont Mining Corporation, 2006a, p. 16). Newmont announced the completion of the permitting process for a proposed 200-megawatt coal-fired powerplant in Elko County. Once completed in the late 2007, the powerplant will provide long-term, reliable electricity to the majority of Newmont's Nevada operations. The current plans call for utilization of 75% of the power generated and sale of 25% to local power companies (Newmont Mining Corporation, 2006b)

Barrick was the Nation's leading gold mining company in 2005, when Placer Dome production was included, reported recovering 90,200 kg (reported as 2.9 million troy ounces) of gold with the majority coming from mines in Elko, Eureka,, Humboldt, Lander, and White Pine Counties (Barrick Gold Corporation, 2006, p. 18-19).

On November 18, Apollo sold its Nevada assets, which included the Florida Canyon Mine, the Standard Mine, and four other exploration properties, to Jinpangu, Inc (Tokyo Japan) for $14 million (Apollo Gold Corporation, 2006, p. 13). In 2005, the Standard Gold Mine near Winnemucca, produced about 653 kg (reported as 21,000 troy ounces) of gold, and the Florida Canyon Mine produced 908 kg (reported as 29,200 troy ounces) of gold (Driesner and Coyner, 2006, p. 5-12).

Exploration continued to increase in the State as companies searched for high-grade veins in and around old districts. In 2005, the State of Nevada had almost 167,000 mining claims, a 14% increase compared with 2004. At least 60 projects were drilled by 38 junior companies, and 50 projects developed by major or mid-tier companies were recorded in 2005, a 63% increase compared with that of 2004 (Muntean and Castor, 2006).

New Mexico.—Gold production in New Mexico is a byproduct of copper production at Phelps Dodge's Ivanhoe concentrator. In 2005, gold production was 231 kg (Lucas Kamat, S.A., 2006).

South Dakota.—Goldcorp Inc. (Toronto, Ontario, Canada) owned and Wharf Resources Inc. operated the Wharf open pit gold mine near Lead, which produced about 1,940 kg (reported as 62,500 troy ounces) of gold (Goldcorp Inc., 2006, p. 8).

Utah.—Rio Tinto plc's Bingham Canyon Mine [which was operated by Kennecott Utah Copper Corp. (Magna, Utah)] produced 12,500 kg of gold as a byproduct of its copper mining operations near Salt Lake City. Long ranked as one of the Nation's principal gold producing mines, Bingham Canyon was the sixth ranked gold producer and leading mine outside Nevada in 2005. Kennecott also operated the nearby Barney's Canyon Mine, an open pit and heap-leaching operation that produced 498 kg of gold (Rio Tinto plc, 2006, p. 10).

Washington.—The Kettle River Gold Mine, Ferry County, the only gold mine in Washington State, was closed, and its workers were dismissed. The owner, Kinross Gold (Toronto, Ontario, Canada), announced that the mine was out of ore, and retrenchment was started (Platts Metals Week, 2005a).

World Industry Structure

World gold mine production in 2005 was 1% higher than that in 2004. Increased mine production in Australia, China, Mali, Mexico, and Peru more than offset the reductions in production from Canada, Botswana, South Africa, and Zimbabwe. In 2005, the top 10 gold producing countries—South Africa, Australia, United States, China, Peru, Russia, Indonesia, Canada, Uzbekistan and Papua New Guinea (in descending order)—accounted for almost 75% of global production. The next 10 leading gold producing countries accounted for another 15%, while the remaining 70 countries made up the last 10% of global gold production in 2005.

According to its annual review of world gold supply and demand, Gold Fields Mineral Services Limited (GFMS) calculated that the total global supply of gold in 2005 was 4,040 t compared with the previous year's total supply of 3,850 t. GFMS also reported increases in official sector sales (40%) and mine production (2%), no net producer hedging, and no implied net disinvestment for sales of bars and coins by private investors. Old gold scrap levels increased by less than 2% in 2005 compared with 2004 old scrap production (Klapwijk and others, 2006, p. 7).

On the consumption side, GFMS reported that total fabrication, including the use of scrap, was 117,000 kg more than its 2004 level. Jewelry fabrication increased by 99,000 kg owing to higher demand, particularly in East Asia and India. Coin fabrication was down by 3%, and increases from Canada and Turkey were offset by reductions in the United States and other countries. The amount of gold used in electronics rose by 5% to a 5-year high, which reflected a strong growth across all electronic applications in Japan and the United States. Gold used in dentistry declined in 2005 owing to a reduction in use in Germany. Other industrial and decorative uses increased by 3%. Gold used in medals and for imitation coins, increased by 41% because of the popularity of inexpensive gold pieces in India (Klapwijk and others, 2006, p. 78-107).

World Review

Australia.—Australian gold production in 2005 grew to 262,000 kg, an increase of 3,000 kg compared with that of 2004. With more than a dozen new mines in Australia expecting to produce in 2006 and more mines in the exploration phase, Australia could soon become the leading gold-producing country in the world (Forster, 2006)

Canada.—Canada ranked eighth in world gold production, as its output dropped by more than 8% to 119,000 kg, the lowest level since 1987 (table 8). Additional production from new mines failed to replace production reductions from mine closures in Quebec and Nunavut (Chevalier, 2006§[1]).

China.—China has become a popular location for gold exploration in recent years, and more than 60 non-Chinese

[1]References that include a section mark (§) are found in the Internet References Cited section.

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companies are exploring for gold in China (Beijing Antaike Information Development Co., Ltd., 2006). China's production of gold increased by 5% in 2005 to 225,000 kg compared with 2004 gold production.

Indonesia.—Gold output increased to about 140,000 kg in 2005. Most of the gold was byproduct of copper mining at the Grasberg Mine. Grasberg regained its title as the world's leading gold-producing mine and yielded 107,000 kg, a 123% increase compared with production in 2004. This increase in gold production from the Grasberg Mine was a result of a full recovery after multiple landslides in 2003 (Klapwijk and others, 2006, p. 44).

Papua New Guinea.—On October 9, a landslide caused two deaths and shut down the Lihir Gold Limited (Papua New Guinea) operations on Lihir Island. Full production resumed in early November. Lihir Gold estimated production in 2005 to be 19,000 kg of gold, with a loss of more than 5,000 kg in the third quarter owing to the landslide (Lihir Gold Limited, 2005).

Peru.—In 2005, production of gold in Peru increased by 20% compared with production in 2004, and Peru was the fifth ranked gold producer in the world. Gold production rose to 208,000 kg in 2005 from 9,000 kg in 1990. The 2,211% increase was owing to the promining stance of the Government and the discovery of several large deposits.

The Newmont and Compañía de Minas Buenaventura (Lima, Peru) jointly owned Yanacocha Mine in the Cajamarca district was the world's second ranked gold-producing mine. In 2005, Yanacocha produced an all-time record 104,000 kg (reported as 3,333,088 troy ounces). The total reserves for Yanacocha were estimated to be 1,010 t (reported as 32.6 million troy ounces) (Compañía de Minas Buenaventura, 2006, p. 12) Barrick's Laguna Norte entered into production in the second quarter and produced 17,100 kg (reported as 550,000 troy ounces) of gold in 2005 (Barrick Gold Corporation, 2006, p. 20).

Philippines.—The first gold bar was poured from gold mined at the polymetallic Rapu Rapu Mine in the Philippines on July 19. The mine owner, Lafayette Mining Limited (Melbourne, Victoria, Australia), projected that the mine would produce 1,600 kilograms per year (kg/yr) of gold (Platts Metals Week, 2005b).

The Philippine Supreme Court approved construction of the nation's first large-scale gold operation funded completely by foreign investors. Australian mining company Climax Mining Limited planned to start construction of the Dinkidi gold and copper project in 2006, with production starting by the end of the first-half of 2007 (Mining Engineering, 2005).

Russia.—In 2005, Russian gold production rose to 169,000 kg, up by 4% from 2004 gold production of 163,000 kg. The Russian gold industry has more than 900 entities producing gold, of which the top 10 gold producers control nearly 50% of the gold mining. The leading gold producer in Russia in 2005 was Polyus Gold Mining Company (Moscow, Russia), with 32,300 kg of gold production in 2005. As of December 31, 2005, Polyus's gold reserves were 781,000 kg (reported as 25.1 million troy ounces) (Zemek, 2005; Polyus Gold Mining Company, 2006§).

South Africa.—In 2005, South Africa's gold production of 295,000 kg (a 13% drop compared with gold production in 2004) dropped to its lowest level since 1923. The decrease was attributed to the higher cost of production; in 2005, the total cost of gold production was R89.130 per kilogram compared with R85.200 per kilogram in 2004. The cost increase was partially attributed to the weak rand-based price of gold in 2005 (CRU Week in the News, 2006§).

Venezuela.—The Venezuelan Government announced a review of gold and diamond mining concessions and contracts to determine if they are idle. If the Government determines that the foreign-operated mines are not being fully exploited, the mines will be seized and turned over to small scale miners or the new National Mining Company (Platts Metals Week, 2006).

Outlook

Worldwide consolidation will continue in the gold industry as gold producers seek to secure their assets, increase gold reserves, cut costs, and exploit gold's higher prices. Several new mines are expected to open and older mines to reopen or expand production in 2006. Domestic and world exploration spending for new gold resources is expected to continue to increase and focus on areas of historical gold production.

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TABLE 1
SALIENT GOLD STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Production:						
Mine:						
Quantity	kilograms	335,000	298,000	277,000	258,000	256,000
Value	thousands	$2,940,000	$2,980,000	$3,250,000	$3,400,000	$3,670,000
Gold recovered by cyanidation:						
Extracted in vats, tanks, closed containers[2]	kilograms	117,000	99,600	89,000	9,940	W
Leached in open heaps or dumps[3]	do.	195,000	177,000	174,000	234,000	234,000
Refinery:						
Concentrates and dore	do.	191,000	196,000	194,000	222,000	163,000
Recycled materials (new and old scrap)	do.	82,700	78,100	89,100	91,700	75,600
Exports, refined	do.	395,000	185,000	220,000	114,000	182,000
Imports for consumption, refined	do.	161,000	172,000	152,000	139,000	105,000
Net deliveries from foreign stocks in Federal Reserve Bank of New York	do.	259,000	40,000	55,000	3,000	--
Stocks, December 31:						
Industry[4]	do.	3,670	3,490	3,590	1,080	2,040
Gold exchange traded funds holdings, United States only	metric tons	--	--	--	95	285
Commodity Exchange (COMEX)[5]	kilograms	38,000	63,900	97,100	180,000	211,000
U.S. Department of the Treasury	metric tons	8,120	8,140	8,140	8,140	8,140
U.S. Gold Futures Trading[6]	do.	21,100	28,000	38,000	46,500	49,400
Consumption:						
U.S. Department of the Treasury:[7]						
American Eagle gold coin	kilograms	10,700	12,500	16,200	15,100	15,100
Other numismatic gold coins	do.	250	370	422	16	17
In industry and the arts	do.	179,000	163,000	183,000	185,000	183,000
Price, average[8]	dollars per troy ounce	272.22	311.33	364.80	410.52	446.20
Employment, mine and mill only[9]		9,500	7,600	7,300	7,550	7,910
World:						
Production, mine	kilograms	2,560,000	2,550,000	2,560,000 r	2,440,000 r	2,470,000
Official bullion reserves[10]	metric tons	33,000	32,200	31,800	31,400	30,800

rRevised. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Data are rounded to no more than three significant digits, except prices.

[2]May include small quantities recovered by gravity methods.

[3]May include tailings, waste-ore dumps, and previously mined ore at some inactive mines.

[4]Unfabricated refined gold held by refiners, fabricators, dealers, and the U.S. Department of Defense.

[5]Commodity Exchange (COMEX) Division of the New York Mercantile Exchange.

[6]COMEX only.

[7]Fiscal year bullion disbursements to U.S. Mint coin programs. Fiscal year begins October 1 of year prior to year indicated.

[8]Engelhard Corp. industries quotation.

[9]Data from the Mine Safety and Health Administration.

[10]Held by central banks, governments, and international monetary organizations. Data from the International Monetary Fund.

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TABLE 2
MINE PRODUCTION OF GOLD IN THE UNITED STATES, BY STATE[1]

(Kilograms)

State	2004	2005
California	3,260	W
Nevada	216,000	212,000
Other States[2]	38,800	44,200
Total	258,000	256,000

W Withheld to avoid disclosing company propriety data; included with "Other States."
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes Alaska, Arizona, Colorado, Idaho, Montana, New Mexico, South Dakota, Utah, Washington, and data indicated by symbol W.

TABLE 3
LEADING GOLD-PRODUCING MINES IN THE UNITED STATES IN 2005, IN ORDER OF OUTPUT[1]

Rank	Mine	County and State	Majority Owner	Quantity (kilograms)
1	Betze-Post	Eureka, NV	Barrick Gold Corp.	47,100
2	Eastern Nevada Operations	do.	Newmont Mining Corporation	43,500
3	Cortez	Lander, NV	Placer Dome Inc.	28,100
4	Smoky Valley Common Operation	Nye, NV	Kinross Gold Corporation	23,300
5	Meikle	Elko, NV	Barrick Gold Corp.	15,800
6	Bingham Canyon[2]	Salt Lake, UT	Kennecott Minerals Company	12,500
7	Lone Tree	Humboldt, NV	Newmont Mining Corporation	10,600
8	Cresson	Teller, CO	Cripple Creek & Victor Gold Mining Co.	10,300
9	Fort Knox[3]	Fairbanks, AK	Kinross Gold Corporation	10,200
10	Twin Creeks	Humboldt, NV	Newmont Mining Corporation	8,320
11	Turquoise Ridge	do.	Placer Dome Inc.	6,490
12	Marigold	do.	Glamis Gold Ltd.	6,390
13	Jerritt Canyon	Elko, NV	Queenstake Resources Ltd.	6,350
14	Midas	do.	Newmont Mining Corporation	5,200
15	Robinson	White Pine, NV	Quadra Mining Ltd.	2,520
16	Golden Sunlight	Jefferson, MT	Placer Dome Inc.	2,510
17	Bald Mountain	White Pine, NV	do.	2,500
18	Greens Creek	Juneau, AK	Kennecott Minerals Company	2,270
19	Coeur Rochester	Pershing, NV	Coeur d'Alene Mining Corporation	2,190
20	Kettle River	Ferry, WA	Kinross Gold Corporation	2,130
21	Wharf	Lawrence, SD	Wharf Resources, Inc.	1,940
22	Mule Canyon[4]	Lander, NV	Newmont Mining Corporation	1,490
23	Montana Tunnels	Jefferson, MT	Apollo Gold Corp.	1,390
24	Denton-Rawhide	Mineral, NV	Kennecott Minerals Company	1,090
25	Florida Canyon	Pershing, NV	Jipangu Inc.	908
26	Golden Wonder	Hinsdale, CO	LKA International	794
27	Mesquite	Imperial, CA	Western Goldfields, Inc.	778
28	Standard	Pershing, NV	Jipangu Inc.	669
29	Barney's Canyon	Salt Lake, UT	Kennecott Minerals Company	498
30	Briggs	Inyo, CA	Canyon Resources Corp.	289

[1]Data are rounded to no more than three significant digits; the mines on this list accounted for more than 99% of U.S. mine production in 2005.
[2]Mine production refers to total quantity of gold produced in concentrates.
[3]Mine production refers to gold equivalent produced.
[4] Prior to 2004, included with "Newmont Nevada Operations."

Sources: Company annual reports, company 10-K reports submitted to the Securities and Exchange Commission, company news releases, and Nevada Bureau of Mines and Geology.

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TABLE 4
U.S. EXPORTS OF GOLD, BY COUNTRY[1, 2]

Year and country	Ores and concentrates[3]		Dore and precipitates		Refined bullion[4]		Total	
	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
2004	1,150	$10,200	142,000	$1,860,000	114,000	$1,500,000	257,000	$3,370,000
2005:								
Argentina	--	--	--	--	215	3,080	215	3,080
Armenia	--	--	--	--	54	760	54	760
Aruba	34	380	--	--	--	--	34	380
Australia	1	5	--	--	1,980	29,900	1,980	29,900
Austria	--	--	--	--	(5)	6	(5)	6
Bahamas, The	(5)	3	--	--	--	--	(5)	3
Belgium	--	--	--	--	2	22	2	22
Brazil	--	--	--	--	708	9,680	708	9,680
Canada	2	33	12	165	724	10,200	738	10,400
Cayman Islands	--	--	--	--	(5)	5	(5)	5
China	--	--	1	10	48	708	49	718
Costa Rica	--	--	--	--	305	4,240	305	4,240
Denmark	1	6	--	--	--	--	1	6
Dominican Republic	1,080	10,300	--	--	3	32	1,080	10,300
France	(5)	3	--	--	11	169	11	173
Germany	19	156	5	74	1,920	27,600	1,940	27,800
Guatemala	--	--	--	--	673	9,740	673	9,740
Hong Kong	2	17	--	--	6,260	91,000	6,270	91,000
India	--	--	--	--	2,500	34,400	2,500	34,400
Indonesia	--	--	--	--	219	3,070	219	3,070
Ireland	46	301	--	--	1	9	47	310
Israel	--	--	--	--	431	6,150	431	6,150
Italy	1	10	--	--	3	39	4	49
Japan	--	--	--	--	4,490	63,300	4,490	63,300
Korea, Republic of	(5)	10	1	10	5	83	6	103
Malaysia	--	--	1	10	975	13,400	976	13,400
Mexico	--	--	--	--	5,980	82,700	5,980	82,700
Netherlands Antilles	88	822	--	--	--	--	88	822
Pakistan	--	--	--	--	56	807	56	807
Panama	--	--	--	--	51	720	51	720
Peru	--	--	--	--	265	3,670	265	3,670
Philippines	11	127	--	--	--	--	11	127
Singapore	3	28	--	--	3,510	47,800	3,510	47,900
Switzerland	--	--	139,000	1,990,000	58,200	800,000	197,000	2,790,000
Taiwan	2	14	--	--	1,000	14,000	1,000	14,000
Thailand	--	--	--	--	5,980	84,800	5,980	84,800
Trinidad and Tobago	--	--	--	--	14	204	14	204
Turkey	--	--	--	--	38	520	38	520
United Arab Emirates	--	--	--	--	22,200	305,000	22,200	305,000
United Kingdom	86	1,230	2,010	28,200	62,800	902,000	64,900	931,000
Venezuela	--	--	--	--	14	189	14	189
Vietnam	--	--	--	--	97	1,360	97	1,360
Total	1,380	13,400	141,000	2,020,000	182,000	2,550,000	324,000	4,580,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Ash and residues data were zero for listed years.

[3]Includes base-metal ores, concentrates, and matte destined for refining.

[4]Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Monetary gold is excluded.

[5]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 5
U.S. EXPORTS OF GOLD, BY COUNTRY[1]

Year and country	Waste and scrap		Metal powder		Gold compounds	
	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
2004	725,000	$815,000	647	$8,670	1,170,000	$29,000
2005:						
Argentina	--	--	--	--	210	4
Armenia	--	--	185	2,700	--	--
Australia	--	--	(2)	3	165	3
Austria	28	422	--	--	--	--
Bahamas, The	--	--	--	--	323	6
Belgium	395	5,130	--	--	--	--
Brazil	--	--	--	--	374	9
Canada	127,000	472,000	15	166	291,000	5,240
China	453	92	2	8	17,200	318
Dominican Republic	--	--	--	--	47,900	863
Eritrea	--	--	2	19	--	--
France	--	--	16	160	306	5
Germany	178,000	99,600	3	42	5,600	83
Guatemala	673	4,870	--	--	--	--
Hong Kong	1	11	4	92	14,900	269
India	--	--	52	683	--	--
Ireland	--	--	3	19	12,400	223
Israel	--	--	16	94	42,600	767
Italy	2,710	2,230	--	--	869	16
Japan	721	6,660	35	377	14,600	263
Korea, Republic of	24	57	74	1,020	1,490	27
Malaysia	7	51	6	40	--	--
Mexico	--	--	11	108	5,900	106
Netherlands	--	--	--	--	20,300	366
New Zealand	--	--	--	--	712	14
Panama	--	--	--	--	3,600	65
Singapore	--	--	2	9	772,000	21,100
South Africa	15	257	--	--	--	--
Spain	--	--	(2)	4	--	--
Sweden	118	451	--	--	--	--
Switzerland	490	7,170	3	37	--	--
Taiwan	--	--	--	--	51,300	924
Thailand	15	3	--	--	--	--
Trinidad and Tobago	--	--	--	--	322	6
Turkey	--	--	37	536	--	--
United Kingdom	253,000	71,600	220	3,150	10,200	206
Vietnam	--	--	2	20	--	--
Total	563,000	670,000	687	9,280	1,310,000	30,900

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF GOLD, BY COUNTRY[1]

Year and country	Ores and concentrates[2] Quantity (kilograms)	Ores and concentrates[2] Value (thousands)	Dore and precipitates Quantity (kilograms)	Dore and precipitates Value (thousands)	Refined bullion[3] Quantity (kilograms)	Refined bullion[3] Value (thousands)	Total Quantity (kilograms)	Total Value (thousands)
2004	1,860	$19,200	142,000	$1,590,000	139,000	$1,830,000	283,000	$3,440,000
2005:								
Aruba	--	--	--	--	1,300	15,800	1,300	15,800
Australia	35	346	35	526	1,470	23,000	1,540	23,800
Belgium	--	--	--	--	(4)	5	(4)	5
Bolivia	--	--	88	1,070	26	399	114	1,470
Brazil	--	--	--	--	10,700	152,000	10,700	152,000
Canada	1,590	18,600	7	121	62,600	905,000	64,200	924,000
Central African Republic	--	--	--	--	2	26	2	26
Chile	--	--	20,200	138,000	6,050	86,800	26,300	225,000
Colombia	--	--	21,700	276,000	1,680	21,900	23,400	297,000
Costa Rica	--	--	12	145	73	504	85	649
Dominican Republic	--	--	4	50	4	31	8	81
Ecuador	--	--	96	1,250	12	149	108	1,400
El Salvador	--	--	--	--	8	92	8	92
Germany	--	--	--	--	4	61	4	61
Ghana	--	--	--	--	26	404	26	404
Guyana	--	--	--	--	77	928	77	928
Honduras	--	--	2,390	30,100	2,400	34,300	4,790	64,400
Hong Kong	--	--	--	--	1,570	24,400	1,570	24,400
India	--	--	--	--	3	41	3	41
Italy	--	--	--	--	1	7	1	7
Jamaica	--	--	--	--	6	61	6	61
Japan	--	--	--	--	105	1,450	105	1,450
Kenya	--	--	--	--	9	120	9	120
Korea, Republic of	--	--	--	--	4	53	4	53
Lebanon	--	--	--	--	4	57	4	57
Mali	--	--	--	--	3	40	3	40
Mexico	(4)	9	1,640	24,300	16,800	242,000	18,400	267,000
Netherlands Antilles	--	--	75	901	88	1,020	163	1,920
Nicaragua	--	--	2,000	25,200	21	260	2,030	25,400
Panama	--	--	396	5,110	256	2,550	651	7,650
Peru	--	--	185,000	1,560,000	--	--	185,000	1,560,000
Russia	--	--	--	--	26	364	26	364
Sierra Leone	--	--	--	--	1	12	1	12
South Africa	--	--	--	--	47	644	47	644
Switzerland	--	--	(4)	3	4	55	5	58
Taiwan	--	--	--	--	24	333	24	333
Tanzania	--	--	--	--	5	58	5	58
United Kingdom	--	--	--	--	6	69	6	69
Uruguay	--	--	--	--	13	178	13	178
Venezuela	--	--	--	--	11	103	11	103
Zimbabwe	--	--	--	--	5	63	5	63
Total	1,630	18,900	234,000	2,060,000	105,000	1,520,000	341,000	3,590,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes base metal ores, concentrates, and matte destined for refining.

[3]Bullion also moves in both directions between U.S. markets and foreign stocks on deposit in the Federal Reserve Bank. Monetary gold is excluded.

[4]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF GOLD, BY COUNTRY[1]

Year and country	Waste and scrap		Metal powder		Gold compounds	
	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)	Quantity (kilograms)	Value (thousands)
2004	20,500	$161,000	10,900	$59,400	60,000	$1,530
2005:						
Aruba	2	18	--	--	--	--
Australia	(2)	3	--	--	--	--
Belgium	85	700	--	--	--	--
Brazil	1	8	--	--	--	--
Canada	5,360	35,100	51	,509	445	15
Chile	440	6,150	1,430	1,790	--	--
China	37	302	--	--	--	--
Colombia	2,100	24,600	--	--	--	--
Costa Rica	1,520	7,540	--	--	--	--
Czech Republic	--	--	--	--	9	7
Dominican Republic	9,850	86,800	123	1,130	--	--
Ecuador	140	1,400	--	--	--	--
El Salvador	342	2,740	--	--	--	--
France	1	7	--	--	--	--
Germany	--	--	3	28	19,000	508
Ghana	15	255	142	810	--	--
Guatemala	51	254	--	--	--	--
Guinea	--	--	2	12	--	--
Honduras	258	2,200	--	--	--	--
Hong Kong	1	5	--	--	--	--
Israel	--	--	87	1,230	707	39
Italy	81	760	2	17	--	--
Japan	--	--	--	--	5,140	236
Korea, Republic of	7	60	--	--	--	--
Malaysia	219	2,190	--	--	--	--
Mali	--	--	3	27	--	--
Mexico	5,670	24,800	101	593	--	--
Netherlands Antilles	112	1,890	--	--	--	--
Nicaragua	188	1,180	8	62	--	--
Panama	592	6,280	--	--	--	--
Philippines	1	21	--	--	--	--
Sierra Leone	--	--	3	26	--	--
Singapore	1	7	--	--	--	--
Spain	25	330	--	--	--	--
Switzerland	--	--	23	299	--	--
Taiwan	13	226	--	--	--	--
Thailand	193	2,380	--	--	--	--
Turkey	4	21	--	--	--	--
United Kingdom	21	369	20	185	4,180	132
Total	27,300	209,000	1,990	6,730	29,500	935

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 8
GOLD: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Kilograms)

Country	2001	2002	2003	2004	2005
Algeria	300	369	365	597	697
Argentina	30,632	32,506	29,749	28,466	30,000 e
Armenia	1,900	3,200	1,800	2,100	1,400
Australia	280,100 r	266,100 r	282,000	259,000	262,000
Belize e	1	1	1	1	1
Benin	16	20	20 e	20 e	20 e
Bolivia	12,395	11,256	9,362	6,951	8,906
Botswana	2	8	9 r, e	162 r	2,770
Brazil[4]	42,884	41,662 r	40,416 r	47,596 r	41,154 p
Bulgaria e	1,540	1,110	2,142 r, 3	2,431 r, 3	2,400
Burkina Faso	229	209	770	1,125	1,397
Burma e	200	200	100	100	100
Burundi	415	483	2,855	3,229 r	3,905
Cameroon	600 r	700	700	1,500 e	1,500 e
Canada	158,875	151,904	140,861	129,478 r	118,528
Central African Republic e	34	16	7 r, 3	7 r, 3	7
Chile	42,673	38,688	38,954	39,986 r	40,447
China e	185,000	192,000	205,000	215,000	225,000
Colombia	21,813	20,823	46,515	37,738 r	35,783
Congo (Brazzaville) e	10	10	75	60	10
Congo (Kinshasa) e	6,100 r	7,600 r	4,100 r	5,700 r	5,700
Costa Rica e	100	100	110	150	500
Cote d'Ivoire	3,672 r	3,570 r	1,313 r	1,219 r	1,638
Cuba e	1,000	1,000	500	500	500
Ecuador[5]	3,005	2,750	3,020	5,158 r	5,416
Equatorial Guinea e	100 r	100 r	100 r	150 r	200
Eritrea	107	--	9	33 r	30
Ethiopia[6]	3,862	3,670	3,875	3,443 r	3,900
Fiji	3,858	3,731	3,250	4,200	2,800
Finland	5,552	4,666	5,409 r	5,004 r	5,000 e
France e	3,000	2,800	1,700	1,500	1,000
French Guiana	4,062 r	3,290 r	3,296 r	2,564 r	2,500 e
Gabon e, 7	70	70	70	300 r	300
Georgia e	2,000	2,000	2,000	2,000	2,000
Ghana	68,341	69,271	70,749 r	63,139 r	62,100 e
Guatemala e	4,500	4,500	4,550	-- r, 3	740 3
Guinea	16,205 r	16,815 r	16,622 r	10,700 r	11,000 e
Guyana	14,183	13,581	12,170	11,462 r	11,400 e
Honduras	4,574	4,984	5,000 e	5,500 e	5,000 e
India[8]	3,700	3,800 e	3,200	3,800	3,900 e
Indonesia[9]	166,091	142,238	141,019	92,936	140,000 e
Iran	192 r	210 r	203 r	195 r	200 e
Italy e	503 3	500	100	--	--
Jamaica	214	328	131	20 e	--
Japan	7,815	8,615	8,143	8,021	8,318
Kazakhstan e	27,100 3	27,000	30,000	30,000	18,062 3
Kenya	1,545	1,477	1,543	567 r	600
Korea, North e	6,600	6,600	6,300	6,000	6,000
Korea, Republic of	24 r	310 r	166 r	233 r	266
Kyrgyzstan e	24,000	17,000	22,476 3	22,000	16,700
Laos	--	--	5,368	4,392	6,338
Liberia	57	42	20 e	110 r	16

See footnotes at end of table.

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TABLE 8—Continued
GOLD: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Kilograms)

Country	2001	2002	2003	2004	2005
Madagascar	-- [r]	-- [e]	10	5 [r]	5 [3]
Malaysia	3,965	4,289	4,739	4,221 [r]	4,300 [e]
Mali	42,288	56,043	45,535	37,974 [r]	44,400 [e]
Mexico	23,543	21,324	20,406	21,818 [r]	30,356
Mongolia	13,675	12,097	11,119	18,600 [6]	19,240
Morocco	1,191	2,747 [r]	1,863	1,200 [r]	1,200 [e]
Mozambique	22	17	63	56	63
Namibia	2,706	2,815 [r]	2,508 [r]	2,205 [r]	2,200 [e]
New Zealand	9,885	9,770	9,300 [r]	10,151 [r]	10,200 [e]
Nicaragua	3,840	3,493	3,029	3,500	3,500
Niger	30	28	30 [r]	684 [r]	700 [e]
Nigeria[e]	37 [3]	40	50	30 [r]	40
Oman	603	188	4	-- [e]	-- [e]
Panama[e]	-- [3]	--	--	200	200
Papua New Guinea[e]	67,043 [3]	63,200 [r]	68,100 [r]	73,500 [r, 3]	66,700
Peru[10]	138,522 [r]	157,530 [r]	172,619 [r]	173,224 [r]	207,822
Philippines	33,840	35,850 [r]	37,844 [r]	35,464 [r]	37,500
Poland	349	296	356 [r]	527 [r]	500
Romania[e]	500 [r]	500 [r]	500 [r]	500 [r]	500
Russia	152,500	168,411 [11]	170,068 [11]	163,148 [r, 11]	169,297 [11]
Rwanda[e]	10	10	2 [3]	--	--
Saudi Arabia[e]	5,000	4,192 [3]	8,769 [3]	9,000	9,200
Senegal[e]	550	600	600	600	600
Serbia and Montenegro[e]	1,100	900 [r]	400 [r]	400 [r]	400
Slovakia	157	77	79 [r]	107 [r]	100
Solomon Islands[e]	300	100	100	10 [r, 3]	10
South Africa	394,800	398,523 [r]	373,300 [r]	340,500 [r]	294,803 [p]
Spain	3,300	5,158	5,362	5,600 [e]	2,500 [e]
Sudan	5,417	5,239	5,106 [r]	5,000 [e]	4,728
Suriname[e]	300	300	300	8,513 [r, 3]	8,500
Sweden	4,986	4,500	4,300 [e]	5,300	5,100 [e]
Taiwan[e]	2 [3]	--	--	--	--
Tajikistan[e]	2,700	2,700	2,700	3,000	3,000
Tanzania	30,088	43,320	48,018	51,010 [r]	54,000
Thailand	320	4,950	4,269	4,500 [r]	4,600 [e]
Turkey[e]	2,000	5,000	6,500	4,500	5,000
Uganda	-- [r]	3	40	1,447 [r]	1,700
United States	335,000	298,000	277,000	258,000	256,000
Uruguay	2,083	2,079	1,550 [r]	1,758 [r]	3,000
Uzbekistan[e]	87,000	90,000 [3]	90,000	93,000	90,000
Venezuela	9,076	9,465	7,900 [e]	9,666	10,000 [e]
Vietnam[e]	3,000	2,000	2,000	2,000	3,000
Zimbabwe	18,050	15,469	12,564	21,330	14,023
Total	2,560,000	2,550,000	2,560,000 [r]	2,440,000 [r]	2,470,000

See footnotes at end of table.

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TABLE 8—Continued

GOLD: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through August 7, 2006.

[3]Reported figure.

[4]Officially reported figures are as follows, in kilograms: Major companies: 2001—37,810; 2002—32,912; 2003—26,066; 2004—28,508 (revised); and 2005—32,803 (preliminary). Garimpos: 2001—5,074; 2002—8,750 (revised); 2003—14,350 (revised); 2004—19,088 (revised); and 2005—8,351 (preliminary).

[5]Includes undocumented artisanal production.

[6]Year ending July 7 of that stated.

[7]Undocumented artisanal production.

[8]Refinery output.

[9]Excludes production from so-called people's mines, which may be as much as 18,000 kilograms per year, but includes gold recovered as byproduct of copper mining.

[10]Includes documented production from placer artisanal production.

[11]Mine output including gold recovered as a byproduct, but excludes secondary gold production, which for Russia in 2002-03 was 2,546 kilograms and 6,835 kilograms, respectively.

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GRAPHITE

By Donald W. Olson

Domestic survey data and tables were prepared by Joseph M. Krisanda, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

In 2005, there was no reported production of natural graphite, but U.S. production of synthetic graphite was estimated to be 209,000 metric tons (t) valued at about $846 million. U.S. imports and exports of natural graphite were estimated to be 64,500 t and 22,100 t, respectively, while U.S. imports and exports of synthetic graphite were estimated to be 51,400 t and 34,100 t, respectively. U.S. apparent consumption of natural and synthetic graphite was estimated to be 42,400 t and 226,000 t, respectively.

This report includes information on U.S. trade and use of natural graphite and U.S. production, trade, and use of synthetic graphite. Trade data in this report are from the U.S. Census Bureau. All percentages in the report were computed using the unrounded data.

Graphite is one of four forms of crystalline carbon; the others are carbon nanotubes, diamonds, and fullerenes. Graphite occurs naturally in metamorphic rocks, such as gneiss, marble, and schist. It is a soft mineral also known by the names black lead, mineral carbon, and plumbago. The word graphite is derived from the Greek word "graphein," to write. It has a Mohs hardness of 1 to 2 and exhibits perfect basal (one-plane) cleavage. Depending on purity, the specific gravity is 2.20 to 2.30. The specific gravity of pure graphite is 2.23. It is gray to black in color, opaque, and usually has a metallic luster; sometimes it exhibits a dull earthy luster. It is flexible but not elastic. It has a melting point of 3,927° C and is highly refractory. Graphite is the most electrically and thermally conductive of the nonmetals and is chemically inert. All these properties combined make graphite desirable for many industrial applications, and both natural and synthetic graphite have industrial uses.

Worldwide, natural graphite deposits occur as lenses or layers of disseminated or massive flakes. Naturally occurring organic carbon may be graphitized at temperatures from 300° C to 1,200° C. These temperatures could be associated with low-grade metamorphism or at the contact between an igneous intrusion and a carbonaceous body. The three principal types of natural graphite, which are amorphous, crystalline flake, and lump, are distinguished by physical characteristics that are the result of major differences in geologic occurrence. Amorphous graphite is formed by the thermal metamorphism of coal. The designation "amorphous" is a misnomer. Its relatively low degree of crystalline order and very fine particle size make it appear amorphous. It is usually less pure than the crystalline flake graphite and, therefore, commands a lower price than its more ordered counterpart. Crystalline flake graphite consists of isolated, flat, plate-like particles with angular, irregular, or rounded edges. It is usually found in layers or pockets in metamorphic rocks. In some deposits, the flake graphite occurs as massive accumulations in lenses, pods, or veins. Lump graphite occurs in veins and is believed to be hydrothermal in origin. It typically appears as massive platy intergrowths of fibrous or acicular crystalline aggregates with the long axis parallel to the enclosing wall rock; the particle size ranges from extremely fine to coarse (Kenan, 1984).

Natural graphite is mined from open pit and underground mine operations. Production from open pit operations is less expensive and is preferred where the overburden can be removed economically. Mines in Madagascar are mostly of this type. In Mexico, the Republic of Korea, and Sri Lanka, where the deposits are deep, underground mining techniques are required.

Beneficiation processes for graphite may vary from a complex four-stage flotation at European and United States mills to simple hand sorting and screening of high-grade ore at Sri Lankan operations. Certain soft graphite ores, such as those found in Madagascar, need no primary crushing and grinding. Typically, such ores contain the highest proportion of coarse flakes. Ore is sluiced to the field washing plant where it undergoes desliming to remove the clay fraction and is subjected to a rough flotation to produce a concentrate with 60% to 70% carbon. This concentrate is transported to the refining mill for further grinding and flotation to reach 85% carbon. It is then screened to produce a variety of products marketed as flake graphite that contain 75% to 90% carbon.

Legislation and Government Programs

As of December 31, 2005, the National Defense Stockpile (NDS), maintained by the U.S. Department of Defense, contained no graphite inventories. All stockpiled graphite inventories were sold during 2004 (Jenkins, 2005).

Production

The U.S. Geological Survey (USGS) obtained the production data in this report through a voluntary survey of U.S. synthetic graphite producers. The survey of U.S. synthetic graphite producers collected data from 21 of 22 canvassed producers. Data were estimated for the producer that did not respond to the survey based on responses received in previous years and on industry trends.

No natural graphite was reported mined in the United States in 2005, but 209,000 t of synthetic graphite with an estimated value of $846 million was reported produced and shipped (table 3).

Consumption

The USGS obtained the data in this report through a survey of natural graphite companies in the United States. The survey of natural graphite companies collected data from 82 of 98 canvassed companies and plants. Data were estimated for the companies that did not respond to the survey. This survey represented most of the graphite industry in the United States.

Graphite uses have changed dramatically in the past 20 years.

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U.S. consumption of natural graphite decreased slightly by about 3% to 43,200 t in 2005 from 44,300 t in 2004 (table 2). The natural graphite consumption data in table 2 include mixtures of natural and synthetic graphite with the amorphous graphite. Consequently, the table 2 consumption numbers are higher than the computed apparent consumption numbers given in table 1. Consumption of crystalline grade increased in 2005 by more than 4% to 22,400 t from 21,500 t in 2004, and consumption of amorphous grade decreased by almost 9% to 20,800 t in 2005 from 22,900 t in 2004. These changes in end use corresponded with a 3% decrease in total graphite value in 2005. Brake linings, refractories, and steelmaking were the three industries that dominated U.S. natural graphite use. Brake linings and refractories accounted for 42% of natural graphite consumption. Foundries and lubricants industries together made up another 5% of consumption. The refractories industry was the leading consumer of crystalline flake graphite, increasing its graphite use compared with 2004.

Graphite has properties of both metals and nonmetals, which makes it suitable for many industrial applications. The metallic properties include electrical and thermal conductivity. The nonmetallic properties include high thermal resistance, inertness, and lubricity. The combination of conductivity and high thermal stability allows graphite to be used in many applications, such as in batteries, fuel cells, and refractories. Graphite's lubricity and thermal conductivity make it an excellent material for high-temperature applications because it provides effective lubrication at a friction interface while furnishing a thermally conductive matrix to remove heat from the same interface. Electrical conductivity and lubricity allow its use as the primary material in the manufacture of brushes for electric motors. A graphite brush effectively transfers electric current to a rotating armature while the natural lubricity of the brush minimizes frictional wear. Today's advanced technology products, such as friction materials and battery and fuel cells, require high-purity graphite.

Refractory applications of graphite included carbon-bonded brick, castable ramming, and gunning mixtures. Carbon-magnesite brick has applications in high-temperature corrosive environments, such as iron blast furnaces, ladles, and steel furnaces. Carbon-alumina linings are principally used in continuous steel-casting operations. Alumina- and magnesite-carbon brick requires a particle size of 100 mesh and a purity of 95% to 99% graphite.

Crystalline flake graphite accounted for almost 53% of natural graphite usage in the United States. It was consumed mainly in batteries, brake linings, lubricants, other applications, and refractories. Amorphous graphite is mainly used in brake linings, refractories, steelmaking, and other applications where additions of graphite improve the process or the end product. Lump graphite finds appropriate uses in a number of areas, such as steelmaking, depending on purity and particle size.

Synthetic graphite is most often chosen in North America instead of natural graphite and accounts for a significant share of the graphite market. The main market for high-purity synthetic graphite is as a carbon-raiser additive in iron and steel. This market consumes a significant portion of the synthetic graphite. Other significant uses of all types of graphite are in the manufacture of catalyst supports; low-current, long-life batteries; porosity-enhancing inert fillers; powder metallurgy; rubber; solid carbon shapes; static and dynamic seals; steel; and valve and stem packing. The use of graphite in low-current batteries is gradually giving way to carbon black, which is more economical.

Graphite is used to manufacture antistatic plastics, conductive plastics and rubbers, electromagnetic interference shielding, electrostatic paint and powder coatings, high-voltage power cable conductive shields, membrane switches and resistors, and semiconductive cable compounds, and electrostatic paint and powder coatings (George C. Hawley, President, George C. Hawley and Associates, written commun., January 16, 2004).

Prices

Natural graphite prices increased for all types during 2005. Prices for crystalline and crystalline flake graphite concentrates ranged from $410 to $795 per metric ton; prices for amorphous powder ranged from $240 to $260 per ton (table 4). Ash and carbon content, crystal and flake size, and size distribution affect the price of graphite. The Swiss border price of synthetic graphite in 2005 was $2,007 per ton. The average unit value of synthetic graphite exports increased by 44% to $2,729 per ton in 2005 from $1,901 per ton in 2004 (table 5).

Foreign Trade

Total graphite exports decreased by about 41% in tonnage to 56,200 t valued at $109 million in 2005 from 94,900 t valued at $118 million in 2004 owing to a 52% and 30% decrease in natural and synthetic graphite exports, respectively (table 5). Total natural graphite imports increased slightly in tonnage to 64,500 t in 2005 from 63,700 t in 2004, and the value increased by 16% to $34.7 million in 2005 from $29.9 million in 2004 (table 6). Principal import sources of natural graphite, in descending order of tonnage, were China, Mexico, Canada, Brazil, and Madagascar, which accounted for about 98% of the tonnage and 88% of the value of total imports. Mexico and China, in descending order of tonnage, were the suppliers of amorphous graphite, and Sri Lanka provided the lump and chippy dust variety. China and Canada, in descending order of tonnage, were the major suppliers of crystalline flake and flake dust graphite. A number of other producing nations supplied several other natural types and grades of graphite to the United States; among the most notable were Canada and the United Kingdom.

World Review

World production of natural graphite increased by 3% in 2005 to an estimated 1.05 million metric tons (Mt) compared with 1.02 Mt in 2004. China maintained its position as the world's leading graphite producer with 720,000 t. India was the second ranked graphite producer with 130,000 t, followed by Brazil, North Korea, and Canada, in decreasing order of tonnage produced. These five countries accounted for 94% of world production, and China alone accounted for about 68% (table 8).

Research and Technology

New technology in processing and treatment expanded the use of natural graphite in battery applications. Graphite for these applications is purified to 99.9% carbon content. Most new uses for graphite products are being developed through advances in graphite

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thermal technology. The ability to refine and modify graphite and other carbon products is expected to be the key to future growth in the graphite industry. Innovative refining techniques have enabled the use of improved graphite in electronics, foils, friction materials, and lubrication applications (Hand, 1997). One of the new application areas is in electrically conductive asphalt for heated runways at airports and roadway bridges. With its high corrosion resistance, high refractory property, and low specific gravity, graphite is critical for many industrial applications, such as dies for continuous casting, heat exchangers for the chemical industry, and rocket nozzles. The relatively poor wear and oxidation resistance of graphite, however, limit its use. A class of high-performance materials based on titanium-carbide-coated graphite makes the material suitable for some applications that require combined hardness, toughness, and thermal resistance (Webb, 2000). Because titanium carbide is a very hard and durable material, the resulting components are extremely resistant to corrosion, elevated temperatures, and wear. These composites can be engineered for many industrial uses through control of the coating composition, microstructure, surface finish, and thickness. In metal melting applications, titanium-carbide coatings have been shown to improve the service life of graphite components by as much as fivefold.

Graphite is formed of parallel sheets of carbon atoms in a hexagonal arrangement. It is possible to insert other atoms between the sheets, a process that is called intercalation. The insertion of other atoms makes dramatic changes in the properties of graphite. Lithium ions can be inserted to create graphite anodes for lithium ion batteries. Graphite can be intercalated with sulfuric and nitric acid to produce expanded graphite from which foils are formed that are used in seals and gaskets and are beginning to be used in fuel cells (Hawley, 2001).

Outlook

Refractory use trends for graphite closely follow events in the steel industry because graphite is used in the manufacture of refractory brick used in iron and steel furnace linings. Graphite-base refractories are also used as continuous casting ware usually in the form of nozzles to guide molten steel from ladle to mold. Brake linings and other friction materials are expected to steadily use more natural graphite as new automobile production continues to increase and more replacement parts are required for the growing number of vehicles. Natural graphite (amorphous and fine flake) is used as a substitute for asbestos in brake linings for vehicles heavier than cars and light trucks. Flexible graphite products, such as grafoil (a thin graphite cloth), are expected to be the fastest growing market but are expected to use small amounts of natural graphite compared with major end-use markets, such as brake linings and refractories. Products produced by advanced refining technology in the next few years, despite a weak refractory market and competitive pricing from Chinese material, could increase profitability in the U.S. graphite industry.

The predicted increase in manufacture and sales of hybrid and electric vehicles is expected to increase demand for high-purity graphite in fuel-cell and battery applications. Fuel cells are a potential high-growth, large-volume graphite (natural and synthetic) end use, but are currently a very small part of consumption. High volumes of graphite are not expected to be consumed in this end use for many years, but may be used in the longer term (Taylor, 2006, p. 517). One prediction is that the demand for high-quality, high-carbon graphite could increase to more than 100,000 metric tons per year (t/yr) for fuel-cell and battery applications alone (Crossley, 2000).

Global demand for graphite used in batteries may increase to more than 25,000 t/yr in the next 4 to 5 years. This demand is expected to be spread between two main consuming sectors—alkaline batteries and lithium-ion batteries. Synthetic and natural graphite are used in these batteries. In alkaline batteries, graphite is the conductive material in the cathode. Until recently, synthetic graphite was predominantly used in these batteries. With the advent of new purification techniques and more efficient processing methods, it has become possible to improve the conductivity of most natural graphite to the point where it can be used in batteries. The decision whether to use synthetic or natural graphite will be based on performance and price. The growth of the lithium-ion battery market could have a more dramatic effect on the graphite market as the demand for mobile energy storage systems rises.

There is a common industry trend towards higher purity and consistency in specifications for some specialized and high-tech applications. The trend to produce higher purity graphite using thermal processing and acid leaching techniques continues. High-purity graphite has applications in advanced carbon-graphite composites.

The markets for graphite used in rubber and plastics (including Styrofoam coatings) are growing, and continued growth is expected. The market for graphite in pencils has almost disappeared; pencil "leads" now are imported directly from China (Taylor, 2006, p. 517). These markets, however, use little graphite and are not expected to have a significant impact on future consumption.

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TABLE 1
SALIENT NATURAL GRAPHITE STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Apparent consumption[2]	metric tons	28,200	23,600	30,000	17,600	42,400
Exports:						
Quantity	do.	23,900	21,600	22,200	46,100	22,100
Value	thousands	$16,900	$19,200	$19,500	$24,900	$15,900
Imports for consumption:						
Quantity	metric tons	52,100	45,100	52,300	63,700	64,500
Value	thousands	$23,300	$22,300	$24,400	$29,900	$34,700
World, production	metric tons	816,000 r	932,000 r	999,000 r	1,020,000 r	1,050,000 e

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits.

[2]Domestic production plus imports minus exports.

TABLE 2
U.S. CONSUMPTION OF NATURAL GRAPHITE, BY END USE[1]

	Crystalline		Amorphous[2]		Total	
End use	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
2004:						
Batteries	W	W	W	W	W	W
Brake linings	W	$1,370	3,960	$2,930	W	$4,300
Carbon products[3]	251	486	212	248	463	733
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	W	W
Foundries[4]	W	457	W	631 r	W	1,090
Lubricants[5]	2,040 r	2,380	W	W	W	W
Pencils	W	W	W	39	W	W
Powdered metals	367	500	W	W	W	W
Refractories	6,900 r	3,420 r	4,330	3,180	11,200 r	6,600 r
Rubber	W	W	377	W	W	360
Steelmaking	W	W	W	8,130 r	W	W
Other[6]	W	7,460 r	W	W	9,310	W
Total	21,500	20,100 r	22,900 r	19,200 r	44,300 r	39,300 r
2005:						
Batteries	W	W	--	--	W	W
Brake linings	2,570	1,900	3,930	3,150	6,510	5,050
Carbon products[3]	286	784	W	W	W	W
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	W	225
Foundries[4]	178	137	W	634	W	771
Lubricants[5]	768	808	W	W	W	W
Pencils	W	W	W	W	W	W
Powdered metals	283	463	18	44	300	507
Refractories	7,980	4,280	3,830	2,770	11,800	7,040
Rubber	54	85	W	434	W	520
Steelmaking	W	W	W	W	W	8,970
Other[6]	8,170	8,600	1,120	894	9,290	9,490
Total	22,400	20,400	20,800	17,700	43,200	38,100

rRevised. W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.

[1]Data are rounded to no more than three significant digits.

[2]Includes mixtures of natural and manufactured graphite.

[3]Includes bearings and carbon brushes.

[4]Includes foundries (other) and foundry facings.

[5]Includes ammunition and packings.

[6]Includes antiknock and other compounds, drilling mud, electrical/electronic devices, industrial diamonds, magnetic tape, mechanical products, paints and polishes, small packages, soldering/welding, and other end-use categories.

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TABLE 3

SHIPMENTS OF SYNTHETIC GRAPHITE BY U.S. COMPANIES, BY END USE[1]

End use	Quantity (metric tons)	Value (thousands)
2004:		
Anodes	W	W
Cloth and fibers (low modulus)	W	$130,000
Crucibles and vessels, refractories	W	W
Electric motor brushes and machined shapes	W	W
Electrodes	168,000	363,000
High-modulus fibers	W	72,400
Unmachined graphite shapes	8,120	81,000
Synthetic graphite powder and scrap[2]	W	W
Other	W	W
Total	249,000	774,000
2005:		
Anodes	W	W
Cloth and fibers (low modulus)	W	162,000
Crucibles and vessels, refractories	W	W
Electric motor brushes and machined shapes	W	W
Electrodes	146,000	391,000
High-modulus fibers	7,020	134,000
Unmachined graphite shapes	9,090	85,300
Synthetic graphite powder and scrap[2]	W	W
Other	W	W
Total	209,000	846,000

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1]Data are rounded to no more than three significant digits.

[2]Includes lubricants (alone/in greases), steelmaking carbon raisers, additives in metallurgy, and other powder data.

TABLE 4

REPRESENTATIVE YEAREND GRAPHITE PRICES[1]

(Dollars per metric ton)

Type	2004	2005
Crystalline large, 94% to 97% carbon, +80 mesh	570-750	660-795
Crystalline large, 90% carbon, +80 mesh	480-550	570-655
Crystalline medium, 94% to 97% carbon, +100-80 mesh	560-640	630-710
Crystalline medium, 90% carbon, +100-80 mesh	370-410	440-495
Crystalline medium, 85% to 87% carbon, +100-80 mesh	230-350	450-555
Crystalline fine, 94% to 97% carbon, +100 mesh	450-600	525-640
Crystalline fine, 90% carbon, -100 mesh	350-400	410-475
Amorphous powder, 80%/85% carbon	NA	240-260
Synthetic 99.95% carbon, Swiss border	NA	2,007

NA Not available.

[1]Prices are normally cost, insurance, and freight main European port.

Sources: Industrial Minerals, no. 447, December 2004, p. 72; no. 459, December 2005, p. 70.

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TABLE 5

U.S. EXPORTS OF NATURAL AND SYNTHETIC GRAPHITE, BY COUNTRY[1, 2]

Country	Natural[3]		Synthetic[5]		Total	
	Quantity (metric tons)	Value[4] (thousands)	Quantity (metric tons)	Value[4] (thousands)	Quantity (metric tons)	Value[4] (thousands)
2004:						
Australia	303	$468	917	$2,010	1,220	$2,470
Belgium	192	157	1,850	2,510	2,040	2,670
Brazil	239	155	1,440	4,550	1,680	4,710
Canada	1,810	1,410	10,900	16,400	12,700	17,800
China	1,080	783	4,030	5,860	5,120	6,650
France	684	889	2,810	14,700	3,490	15,600
Hong Kong	18,700	4,080	222	1,650	19,000	5,730
Italy	801	1,520	677	1,400	1,480	2,910
Japan	3,510	1,660	6,720	9,810	10,200	11,500
Korea, Republic of	606	457	2,070	5,650	2,680	6,100
Mexico	9,590	4,280	5,590	6,400	15,200	10,700
Netherlands	226	169	3,570	3,890	3,790	4,060
Taiwan	414	308	823	1,550	1,240	1,860
United Kingdom	2,900	1,780	3,380	7,480	6,280	9,260
Other	5,030	6,790	3,720	8,830 r	8,750	15,600 r
Total	46,100	24,900	48,700	92,700 r	94,900	118,000 r
2005:						
Brazil	1,310	464	1,110	5,060	2,420	5,530
Canada	1,680	1,510	11,700	17,600	13,300	19,100
China	296	310	1,660	6,150	1,960	6,460
France	54	58	3,240	19,300	3,290	19,400
Hong Kong	1,670	1,820	327	2,030	1,990	3,850
Japan	4,650	1,940	2,330	8,240	6,990	10,200
Korea, Republic of	1,030	654	2,520	7,350	3,550	8,000
Mexico	822	701	3,360	5,600	4,180	6,300
Netherlands	425	375	1,030	2,960	1,460	3,340
Taiwan	960	565	678	2,070	1,640	2,630
United Kingdom	5,170	3,270	1,710	4,740	6,880	8,010
Other	4,000	4,280	4,500	12,000	8,500	16,300
Total	22,100	15,900	34,100	93,200	56,200	109,000

rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Numerous countries for which data were reported have been combined in "Other."

[3]Amorphous, crystalline flake, lump and chip, and natural, not elsewhere classified. The applicable Harmonized Tariff Schedule of the United States (HTS) nomenclatures are "Natural graphite in powder or in flakes" and "Other," codes 2504.10.0000 and 2504.90.0000.

[4]Values are free alongside ship.

[5]Includes data from the applicable HTS nomenclatures "Artificial graphite" and "Colloidal or semicolloidal graphite," codes 3801.10.0000 and 3801.20.0000.

Source: U.S. Census Bureau.

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TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF NATURAL GRAPHITE, BY COUNTRY[1, 2]

Country	Crystalline flake and flake dust		Lump and chippy dust		Other natural crude; high-purity; expandable		Amorphous		Total	
	Quantity (metric tons)	Value[3] (thousands)	Quantity (metric tons)	Value[3] (thousands)	Quantity (metric tons)	Value[3] (thousands)	Quantity (metric tons)	Value[3] (thousands)	Quantity (metric tons)	Value[3] (thousands)
2004:										
Brazil	2,650	$3,250	--	--	122	$235	--	--	2,770	$3,480
Canada	13,900	6,710	--	--	386	2,220	--	--	14,300	8,940
China	15,100	5,200	--	--	511	1,010	12,400	$3,210	28,000	9,420
Germany	66	54	--	--	49	167	--	--	115	224
India	76	52	--	--	(4)	45	--	--	76	97
Japan	--	--	--	--	497	2,440	2,780	156	3,280	2,600
Madagascar	1,210	734	--	--	--	--	--	--	1,210	734
Mexico	--	--	620	$1,500	--	--	12,800	1,590	12,800	1,590
Sri Lanka	--	--	--	--	--	--	--	--	620	1,500
United Kingdom	31	27	--	--	342	1,030	--	--	374	1,060
Zimbabwe	20	10	--	--	--	--	--	--	20	10
Other[5]	34	46	--	--	33	199	--	--	66	246
Total	33,100	16,100	620	1,500	1,940	7,360	28,000	4,960	63,700	29,900
2005:										
Brazil	3,110	4,000	--	--	32	81	--	--	3,140	4,070
Canada	9,430	6,440	--	--	527	3,440	--	--	9,960	9,890
China	31,700	12,000	--	--	116	448	1,690	461	33,500	12,900
Germany	22	14	--	--	85	329	--	--	107	343
India	18	21	--	--	--	--	--	--	18	21
Japan	--	--	--	--	139	1,300	--	--	139	1,300
Madagascar	1,620	1,060	--	--	--	--	--	--	1,620	1,060
Mexico	289	90	--	--	--	--	14,800	2,350	15,100	2,440
Sri Lanka	--	--	598	1,530	--	--	--	--	598	1,530
United Kingdom	--	--	--	--	261	874	--	--	261	874
Other[5]	22	31	--	--	58	206	--	--	80	237
Total	46,200	23,700	598	1,530	1,220	6,680	16,500	2,810	64,500	34,700

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]The information framework from which data for this material were derived originated from Harmonized Tariff Schedule of the United States base data.

[3]Customs values.

[4]Less than ½ unit.

[5]Includes Austria, Belgium, Finland (2004), France (2004), Italy, the Netherlands, Sweden, and Switzerland.

Source: U.S. Census Bureau, adjusted by the U.S. Geological Survey.

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TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF GRAPHITE ELECTRODES, BY COUNTRY[1, 2]

Country	Quantity (metric tons)	Value[3] (thousands)
2004:		
Brazil	4,170	$5,040
Canada	5,770	14,400
China	12,600	17,700
France	1,320	2,260
Germany	1,200	6,040
Italy	1,310	3,180
Japan	11,300	28,100
Mexico	42,100	59,700
Russia	2,550	2,810
South Africa	1,470	2,340
Venezuela	1,500	547
Other[4]	1,000	2,020
Total	86,400	144,000
2005:		
Brazil	2,690	5,320
Canada	7,820	20,500
China	14,700	23,000
Germany	1,860	9,900
Japan	12,600	37,000
Mexico	39,400	58,100
Other[4]	2,180	3,380
Total	81,200	157,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]The applicable Harmonized Tariff Schedule of the United States nomenclature is "Electric furnace electrodes," code 8545.11.0000.

[3]Customs values.

[4]Includes data for countries that ship less than 1,000 metric tons per year to the United States.

Source: U.S. Census Bureau.

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TABLE 8
GRAPHITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005
Austria	116	100	100	-- [r]	--
Brazil, marketable	70,091	60,922	70,739 [r]	76,332 [r]	76,500 [e]
Canada[e]	35,000 [r]	25,000	25,000	28,000 [r]	30,000 [e]
China[e]	450,000	629,000	710,000	700,000	720,000
Czech Republic[e]	17,000	16,000	9,000	10,000	10,000
Germany, marketable	3,190 [r]	3,312 [r]	2,840 [r]	3,155 [r]	3,200
India, run-of-mine[e, 3]	140,000	130,000	110,000	120,000	130,000
Korea, North[e]	25,000	25,000	25,000	30,000	32,000
Korea, Republic of	238 [r]	94	58 [r]	247 [r]	250
Madagascar[e]	2,013 [4]	2,000 [r]	15,000 [r]	15,000 [r]	15,000
Mexico, amorphous	21,442	14,065	8,730	14,769 [r]	11,143
Norway[e]	2,500	2,400	2,400	2,300	2,300
Romania	1,176	1,001	--	500 [e]	500 [e]
Russia[e]	6,000	--	--	--	--
Sri Lanka	6,585	3,619	3,387	3,400 [e]	3,000
Sweden[e]	963 [4]	900	850	800	800
Turkey, run-of-mine[5]	15,000 [e]	1,393	942	1,000 [e]	6,000 [e]
Ukraine[e]	7,500	7,500	7,500	7,500	7,500
Uzbekistan[e]	60	60	60	60	60
Zimbabwe	11,836	9,912	7,675	10,267	6,000 [e]
Total	816,000 [r]	932,000 [r]	999,000 [r]	1,020,000 [r]	1,050,000

[e]Estimated. [r]Revised. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through May 8, 2006.

[3]Indian marketable production is 10% to 20% of run-of-mine production.

[4]Reported figure.

[5]Turkish marketable production averages approximately 5% of run-of-mine production. Almost all is for domestic consumption.

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GYPSUM

By Alan Founie

Domestic survey data and tables were prepared by Virginia C. Harper, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

Production of crude gypsum in the United States increased by 23% to 21.1 million metric tons (Mt), and its value increased by 28% to $158 million in 2005 compared with 17.2 Mt valued at $124 million in 2004 (table 1). The United States remained the world's leading producer and consumer of gypsum. Calcined gypsum production decreased by 9% to 21.0 Mt in 2005 compared with 23.2 Mt produced in 2004. Though the exact tonnages were not known by this report's publication date, preliminary figures indicate the use of synthetic gypsum increased by 4% to 9.40 Mt in 2005 from 9.04 Mt in 2004. The use of synthetic gypsum from flue gas desulfurization (FGD) is expected to continue to increase as more coal-fired electric powerplants convert their desulfurization processes to produce marketable gypsum and as more wallboard plants are constructed near these powerplants. Most coal-burning powerplants in the United States are required by U.S. Environmental Protection Agency mandates to install sulfur dioxide removal systems within the next few years, and this has created a significant potential source of gypsum.

Domestic Data Coverage

Gypsum industry data for this report are collected by the U.S. Geological Survey (USGS) from semiannual and annual surveys of gypsum operations and from monthly statistics provided by the Gypsum Association in Washington, DC. In 2005, the USGS annual survey canvassed 107 gypsum production operations that accounted for all known domestic output (figure 1). Ninety-two of the operations canvassed responded. Of the 15 operations that did not respond, 5 were idle or shut down, and production data from the Gypsum Association accounted for 7 more operations. Thus, data are available for 99 out of 102 (97%) of current operations, representing 98% of known production. The output of the producers who did not respond to the survey was determined from public company reports or was estimated from prior year survey responses.

Description and Terminology

Pure gypsum is a white-to-transparent mineral, though impurities can give the mineral a gray, brown, or pink coloration. Its chemical name is calcium sulfate dihydrate, and its chemical formula is $CaSO_4 \cdot 2H_2O$. When gypsum is heated, it loses approximately three-quarters of its water and becomes hemihydrate gypsum ($CaSO_4 \cdot \frac{1}{2}H_2O$), or calcined gypsum, which is soft and can easily be ground to a powder called hemihydrate gypsum plaster or plaster of paris. If the powder is mixed with water to form a slurry or paste, it will dry and set rock hard. As the plaster and water mixture dries, water will chemically recombine with the hemihydrate gypsum, and the material will revert back to the original composition of gypsum. While the hemihydrate gypsum plaster is in slurry form, it can be poured between two paper and adhesive layers to make wallboard, poured into molds, or used to fill cracks and crevices. Gypsum makes an ideal building material because it is abundant, economical, fire resistant, strong, and versatile. It can also reduce the transmission of sound and its use can have other environmental benefits, such as reducing waste delivered to landfills.

Gypsum has been known for centuries as a building material. The earliest known use of gypsum as a building material was in Anatolia around 6000 B.C. Gypsum has been found on surfaces within the great pyramids in Egypt, which were erected in about 3700 B.C. Gypsum is found on every continent in the world and is one of the most widely used minerals. Gypsum mines are located all across North America, and some Western States contain large deposits of powdery gypsum rock (figure 1).

Synthetic gypsum is generated as a byproduct of industrial processes. In the United States, the most common source of synthetic gypsum is FGD systems used to reduce sulfur dioxide emissions from coal-fired electric powerplants. These FGD systems not only keep the air clean but they also can provide a sustainable, ecologically sound source of very pure gypsum. Synthetic gypsum also is generated by various other acid-neutralizing processes.

In the United States, most gypsum is used to manufacture wallboard and plaster for homes, offices, and commercial buildings. An average new American home of 2,000-square-foot floor area uses approximately 7.31 metric tons (t) of gypsum in more than 571 square meters (6,144 square feet) of gypsum wallboard (Mineral Information Institute, 2001). Worldwide, about 51% of total gypsum consumed is used in portland cement. Gypsum is also extensively used as a soil conditioner on large tracts of land in suburban areas and in agricultural regions. As a filler in food products, the average person eats about 28 pounds of gypsum in a lifetime (National Gypsum Company, 2005a§[1]).

Production

The United States continued to lead the world in gypsum production in 2005, accounting for about 17.9% of reported global output (table 8). During 2005, domestic output of crude gypsum increased by 23% to about 21.1 Mt valued at $158 million from that of 2004 (table 1). Crude gypsum was mined by 18 companies in the United States at 45 mines in 14 States (figure 1). More than 87% of the crude gypsum produced was mined by 9 companies at 33 facilities in 14 States. The top gypsum producing States in 2005 were, in descending order of tonnage, Oklahoma, Iowa, Nevada, New York, California,

[1]References that include a section mark (§) can be found in the Internet References Cited section.

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Arkansas, Texas, Indiana, and Michigan. These 9 States with 36 mines produced more than 1 Mt each and together accounted for 17.7 Mt or 84% of the total domestic output of gypsum.

The U.S. gypsum industry consisted primarily of a few large, vertically integrated companies that mined gypsum and manufactured wallboard, plaster, and other gypsum products. Companies with the most mines in 2005 were U.S. Gypsum Corporation (USG) with nine mines; Georgia-Pacific Corporation (GPC) and National Gypsum Company (NGC) each with seven mines; BPB America Inc. (BPB) with five mines; and Harrison Gypsum Company and American Gypsum Company (a subsidiary of the Eagle Materials Corporation) each with three mines. These six companies produced almost 70% of the total U.S. crude gypsum. The 10 leading gypsum mines in the United States accounted for 43% of domestic output in 2005. These 10 mines were owned by 5 companies, and their average output was about 900,000 metric tons per year (t/yr).

During 2005, gypsum was calcined (partially dehydrated by heating) at 58 plants operated by 9 companies in 29 States, principally to produce feedstock for wallboard and plaster manufacturing plants (figure 1). The leading gypsum calcining States in 2005 were, in descending order, Iowa, California, Texas, Nevada, Indiana, Arkansas, and Florida (table 3). These 7 States with 24 plants produced more than 1 Mt of calcined gypsum each and together accounted for about 56% of national output. In 2005, domestic output of calcined gypsum decreased by 9% to 21.0 Mt valued at more than $425 million (table 1).

Companies with the most calcining plants were USG with 21 plants; NGC, 17 plants; GPC, 12 plants; and BPB, 4 plants. These four companies produced more than 91% of the national calcined gypsum output. The 10 leading calcining plants in the United States accounted for more than 35% of production in 2005. These plants were owned by four companies, and the average output of the plants was 738,000 t/yr.

In addition to mined gypsum production, synthetic gypsum was generated as a byproduct of various industrial processes. The primary source of synthetic gypsum was FGD from coal-fired electric powerplants. Eighteen domestic coal-fired powerplants sold synthetic gypsum to the wallboard industry in 2005. Smaller amounts of synthetic gypsum were derived as a byproduct of chemical processes, such as acid neutralization processes, citric acid production, sugar production from sugar beets, and titanium dioxide production. Synthetic gypsum was used as a substitute for mined gypsum, principally for wallboard manufacturing, cement production, and agricultural purposes. In response to USGS surveys, five companies with six operations in six States reported that 285,000 t of synthetic gypsum valued at $1.97 million was produced as a byproduct of processes at their mines and plants and was sold in 2005. In addition to these companies, domestic coal-fired electric powerplants generated approximately 11 Mt of synthetic gypsum from their FGD systems during 2005 (American Coal Ash Association, 2005§). Of the synthetic gypsum generated by domestic coal-fired electric utility FGD systems, 8.4 Mt or 77% was used in 2005 compared with 76% in 2004. Of the total 8.7 Mt of synthetic gypsum consumed during the year, 90% was used for wallboard production, 8% was used in cement and concrete manufacture, and 2% was used in agricultural applications.

Phosphogypsum, another industrial byproduct, is produced in the manufacturing of fertilizers. At present, phosphogypsum is not used in wallboard manufacturing because of the presence of radionuclides, which produce radioactive radon gas as they decay.

The United States gypsum board industry achieved its highest rate of annual shipments ever in calendar year 2005 when U.S. manufacturers of gypsum board shipped a total of 3.36 billion square meters (36.2 billion square feet) of material. This volume represents a 6% increase in shipments compared with the same 12-month period of 2004 when 3.17 billion square meters (34.3 billion square feet) of board was shipped. The 2005 figure represents the fifth consecutive year of increased shipments for the U.S. gypsum board manufacturing industry (Gypsum Today, 2006§).

During 2005, 8 companies manufactured gypsum wallboard products at 77 plants in the United States (figure 2). Wallboard product shipments in 2005 were approximately 2.67 billion square meters (28.7 billion square feet), a decrease of about 7% compared with those of 2004 (table 5). This represented about 77% of the total domestic wallboard products production capacity. The decline was probably the result of temporary plant closings in the Gulf Coast region because of severe hurricanes and flooding. No new wallboard plants were completed in 2005. New plant construction and plant expansions, however, were in progress during the year.

BPB announced plans to build wallboard plants in North Carolina and West Virginia that will use FGD gypsum (Global Gypsum Magazine, 2005a). These plants will each have a capacity of 65 million square meters per year (700 million square feet per year). Lafarge North America Inc. (LaFargeNA) continued upgrading the wallboard plant in Westchester County, NY, by adding a second line. The plant was expected to have the capacity to produce 60 million square meters per year (650 million square feet per year) of wallboard at the completion of expansion in late 2006. Lafarge also planned to expand the Silver Grove, KY, plant (Lafarge Group, 2005a). National Gypsum announced plans to build a high-speed wallboard plant near Charlotte, NC, capable of producing 70 million square meters per year (750 million square feet per year), that will use FGD gypsum generated by Duke Power Company (National Gypsum Company, 2005b§). American Gypsum Company planned to build a new high-speed gypsum wallboard plant using synthetic gypsum under a long-term supply agreement with the South Carolina Public Service Authority, known as Santee Cooper, South Carolina's State-owned electric and water utility, near Georgetown, SC (Eagle Materials Inc., 2005§). This new plant was designed to produce 70 million square meters per year (750 million square feet per year), and construction was expected to begin in late 2005. USG planned to expand the Norfolk, VA, plant (Gypsum Today, 2005§). The combined production of these new wallboard plants and expansions should increase capacity by almost 0.53 billion square meters per year (5.7 billion square feet per year) by 2009, resulting in a 15% increase and raising total wallboard production capacity to about 4.1 billion square meters per year (44.1 billion square feet per year).

There were some major changes in the structure of the gypsum industry in 2005. Cie de Saint-Gobain SA, Europe's leading distributor of building materials, agreed to buy BPB, making Cie de Saint-Gobain SA the world's leading wallboard

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supplier. Also in 2005, Koch Industries, Inc. finalized the purchase of GPC.

Consumption

In 2005 U.S. apparent domestic consumption was more than 41.5 Mt, a 14.7% increase compared with that of 2004. Domestic sources (mined crude plus an estimated 9.4 Mt of synthetic gypsum produced) met more than 73% of domestic consumption requirements; imports satisfied the remaining needs. In 2005, slightly more than 23% of the gypsum consumed in the United States came from synthetic sources, about the same as in 2004.

Gypsum output is categorized as either calcined or uncalcined (table 4). Calcined gypsum was produced domestically from crude gypsum to manufacture wallboard and plaster products. Uncalcined gypsum, used for portland cement production and agriculture, accounted for virtually all remaining consumption during the year. Miscellaneous uses, such as athletic field markings, accounted for only a fraction of 1% of consumption.

In 2005, slightly more than 46% of the calcined gypsum used to manufacture wallboard was consumed in the production of regular ½-inch gypsum board (table 5). Type-X gypsum board, so named because of extra fire retardation qualities, consumed 27% of calcined gypsum. Other regular gypsum board, from ¼- to 1-inch thick, consumed 15%. Fire-resistant wallboard, mobile-home wallboard, water- and moisture-resistant wallboard, lath, veneer base, and sheathing composed most of the balance. Metropolitan areas in the South Atlantic, Pacific, East North Central, and West South Central regions (in decreasing order) were the leading sales areas for gypsum wallboard products.

During 2005, nearly 2.75 Mt, about 70%, of the uncalcined gypsum consumed in the United States was for portland cement production (table 4). Gypsum is added to cement to retard its setting time and makes up about 2% to 6% by weight of cement output (Roskill Information Services Ltd., 2004, p. 294). The remainder of the uncalcined gypsum consumed is used primarily in agriculture. Finely ground gypsum rock was used in agriculture and other industries to neutralize acidic soils, to improve soil permeability, to add nutrients, to stabilize slopes, and to provide catalytic support for maximum fertilizer benefits. Small amounts of high-purity gypsum are also used in a wide range of industrial applications, including the production of foods, glass, paper, and pharmaceuticals.

Recycling

Several million tons of gypsum waste is generated every year by wallboard manufacturing, wallboard installation, and building demolition. Only a small portion of this waste has been recycled in the past, but in 2005, two wallboard manufacturers in the United States entered into new agreements to purchase recycled gypsum from wallboard waste from construction sites (Gypsum Recycling International A/S, 2005§). Initially this will not affect gypsum supplies much, but as more and more waste is generated and room in landfills runs out, recycling could increase.

Gypsum waste generated by the wallboard manufacturing process can be recycled easily. The gypsum core and paper covering are disaggregated and fed back into the raw material stream along with new material. Between 10% and 12% of the wallboard used in new construction and renovation winds up as wallboard scrap. The costs of disposal of this wallboard scrap in solid waste landfills are increasing. In addition to recycling scrap in wallboard plants, wallboard scrap may also be ground and used as a soil conditioner. Wallboard manufacturers and the construction industry have been exploring ways to return this scrap and waste to a plant for recycling. Other potential markets for recycled gypsum waste are in cement production, as a stucco additive, in sludge drying, in water treatment, in grease absorption, and for marking athletic fields.

Prices

In 2005, the average values (free on board, mine or plant) reported by U.S. producers were $7.48 per metric ton for crude gypsum and $20.26 per ton for calcined gypsum (table 4). The average value for plaster reported by domestic producers during the year was $16.66 per 100 kilograms ($7.56 per 100 pounds). The average value of uncalcined gypsum used in agriculture and in cement production was about $17.89 per ton.

During 2005, prices for gypsum wallboard generally increased in response to increased demand. Prices for regular ½-inch wallboard rose in 17 of the 19 major U.S. metropolitan areas that were sampled. Wallboard prices decreased slightly in 2 of the 19 cities. The average wallboard price for 2005 in these 19 cities was $271.44 per 100 square meters ($252.16 per 1,000 square feet). The changes in prices for each metropolitan area ranged from a decrease of $26.95 per 100 square meters ($25.00 per 1,000 square feet) in Pittsburgh, PA, to an increase of $140.14 per 100 square meters ($130.00 per 1,000 square feet) in Cincinnati, OH. At the beginning of the year, prices in these 19 cities ranged during the 12 months beginning in January of 2005 from $172 to $421 per 100 square meters ($160 to $391 per 1,000 square feet). The average of the prices in these 19 cities was $255.83 per 100 square meters ($237.32 per 1,000 square feet) in January and $309.40 per 100 square meters ($287.01 per 1,000 square feet) at yearend. This represented an overall average increase in price of $32.02 per 100 square meters ($29.70 per 1,000 square feet), or 13%, from beginning to yearend 2005 (Engineering News-Record, 2005a, b).

Foreign Trade

In 2005, the United States was the world leader in international trade of gypsum and gypsum products (tables 6, 7). The United States imported crude gypsum from 18 countries and exported gypsum and gypsum products to 69 countries and territories in 2005. Only a small amount of crude gypsum and other gypsum products was exported by the United States in 2005, most of which went to Canada.

Net imports of crude gypsum in 2005 increased by 10% from those of 2004 and accounted for 27% of apparent consumption. Much of this import dependence can be attributed to the lack of adequate domestic gypsum resources near large east and west

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coast wallboard markets. Canada and Mexico accounted for 91% of imported gypsum, while Spain, the Dominican Republic, China, and Jamaica (in descending order) supplied most of the remainder (table 6). Most imports from Canada went to east coast plants, and Mexican sources chiefly served the west coast. Foreign subsidiaries of U.S. gypsum companies produced much of the gypsum that was imported for the wallboard plants. Most of the crude gypsum imported by the United States from Mexico was produced by Compania Minera Caopas de CV and Compania Occidental Mexicana SA de CV (COMSA) in Baja California (Sharpe, 2006). Almost all gypsum imported from Canada came from Nova Scotia. Smaller amounts of imported gypsum were used in portland cement production. The completion of large wallboard manufacturing plants near powerplants along the east coast may affect gypsum imports in the future.

Wallboard exports rose by 3% in 2005, totaling about 9.6 million square meters (103 million square feet) valued at $59 million; they went primarily to countries in Asia, Europe, and Latin America. Wallboard imports increased by 20% in 2005 and totaled 82.3 million square meters (887 million square feet) valued at $129 million.

World Industry Structure

In 2005, 89 countries produced gypsum, 10 of which accounted for 76% of the total world production (table 8). Global natural gypsum production in 2005 was estimated to be 118 Mt, an increase of 3% compared with 2004. More than 200 million metric tons per year of synthetic gypsum (mostly phosphogypsum) is generated worldwide (Roskill Information Services Ltd., 2004, p. 20). However, only a small portion of that gypsum is consumed. North American production accounted for almost 32% of total crude gypsum production. The high demand for gypsum in the United States by the domestic construction industry, which consumes more than one-quarter of total world crude gypsum production, was not matched abroad. This trend may change as European and Asian markets begin to incorporate wallboard in their building styles. The estimate for world production is probably lower than actual production because output that is used by gypsum producers in some countries to make other products onsite is not reported. Additionally, production from small deposits in developing nations was intermittent and in many cases unreported.

Worldwide, the leading use of gypsum is in the manufacture of cement and concrete. In 2004 (the last year worldwide consumption use was available), cement manufacture accounted for about 51% of worldwide gypsum consumption while plaster products, including wallboard, accounted for 39% of all consumption. As a low-value, high-bulk commodity drawn from deposits widely distributed throughout the world, gypsum tended to be consumed within the many countries that mine it. Less than 20% of the world's crude gypsum production was estimated to enter international trade. Only a few countries, such as Canada, Mexico, Spain, and Thailand, were major crude gypsum exporters; of these, Canada and Mexico are significant gypsum exporters because of their large deposits in proximity to large wallboard markets in the United States. Little crude gypsum was exported from the United States.

Although use of gypsum wallboard increased worldwide, only industrialized nations, such as the United States, used gypsum primarily for wallboard products. In developing countries, especially in the Middle East and Asia, most gypsum was used in the production of cement or as a plaster product.

Estimated world production capacity for gypsum wallboard in 2005 exceeded 7.8 billion square meters per year (about 84 billion square feet per year) at more than 250 plants worldwide. Almost one-half of this capacity was in the United States; Asia and Western Europe each accounted for about one-fifth. Construction or expansion of dozens of wallboard plants was underway during the year in many countries, and as in the United States, the use of synthetic gypsum by other industrialized nations increased.

Globally, 2005 marked the commencement of construction of new gypsum facilities and wallboard plants as well as the planning of additional facilities. More and more construction companies worldwide have recognized the economy and convenience of using gypsum board products.

World Review

Asia.—BPB announced plans to expand the wallboard plant in Thailand by adding a second wallboard manufacturing line and to begin construction of a plant in Malaysia that is expected to begin operations by early 2006 (Sharpe, 2006). BPB also announced plans to expand plasterboard capacity in China (Global Gypsum Magazine, 2005e).

The Lafarge Group announced that Lafarge Boral Gypsum in Asia (LBGA) planned to double capacity in China with the Chongqing and the Shanghai plants slated to become operational in 2006. Lafarge also announced construction plans for facilities in the Republic of Korea and Vietnam (Lafarge Group, 2005b, c).

Australia.—Boral Australian Gypsum, Ltd. announced plans to expand the capacity of its wallboard plant in Brisbane, Queensland to 20 million square meters (215.3 million square feet) (Sharpe, 2006).

Canada.—In 2005, Canada continued to be the second ranked North American producer of gypsum. Canadian production totaled 9.4 Mt in 2005, slightly more than in 2004. About 7.7 Mt or 82% of Canadian production was exported to the United States. Two Canadian companies announced that they will open wallboard plants in Nova Scotia and New Brunswick to supply markets in eastern Canada and the New England States in the United States (Sharpe, 2006).

Europe.—In 2005, KnaufGips KG (Knauf) negotiated the use of FGD gypsum from two state-owned coal-fired powerplants in Bulgaria (Global Gypsum Magazine, 2005b). Knauf invested in expanding the capacity of one of its plants in the United Kingdom (Sharpe, 2006). Knauf also began construction of a wallboard plant in St. Petersburg and announced construction of a plant in the Irkutsk region (Sharpe, 2006). Lafarge and BPB also announced plans to construct and upgrade wallboard plants in the United Kingdom (Lafarge Group, 2005b; Sharpe, 2006). BPB announced plans to expand wallboard capacity in France (BPB America Inc., 2005b§). BPB and Lafarge both began construction of wallboard plants in Romania, which were expected to begin

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production in late 2005 or 2006 (Sharpe, 2006).

India.—BPB Indian Gypsum commissioned its third plant in India and announced that it is to construct a fourth Indian plasterboard plant to be ready by mid-2007 (BPB America Inc., 2005b§; Global Gypsum Magazine, 2005c).

Mexico.—Lafarge announced that it will team up with Consorcio Comex SA de CV (Comex) to build a new gypsum production plant in Querearo State (Global Gypsum Magazine, 2005d). BPB and USG also announced plans for wallboard plants in Mexico (Sharpe, 2006). When these plants are complete, there will be five wallboard plants operating in Mexico to meet the rising local demand.

Middle East and Africa.—BPB BPB announced plans for construction of plants in Egypt, South Africa, and Turkey (Harder, 2006). In Saudi Arabia, Lafarge and the United Gypsum Company announced plans for new wallboard plants (Global Gypsum Magazine, 2005f, g). Lafarge also announced plans for a plant in Algeria (Global Gypsum Magazine, 2005d).

South America.—Colombian sources said Etex Group and Lafarge will partner in building a gypsum plasterboard plant in northern Colombia that will be the largest plant of its kind in the Andean region (Global Gypsum Magazine, 2005g).

Outlook

Demand for gypsum products was expected to increase at a rate of 1% to 3% per year through 2010 to about 50 Mt (National Association of Home Builders, 2006§). Unit value was also expected to increase by about 4% per year through 2010. Demand for wallboard was expected to advance to 3.8 billion square meters (41 billion square feet) by 2009.

One of the key economic indicators used by the wallboard and gypsum industry is the number of new housing starts. The residential market is responsible for about 60% of consumption of gypsum products. Housing starts in North America were expected to drop slightly in 2006 and to continue to decrease slightly into 2007 if interest rates rise as expected (National Association of Home Builders, 2006§). Preliminary gypsum production and consumption data for the first part of 2006 suggest that use levels in 2006 will match those of 2005. Drops in housing starts were expected to be offset by remodeling and industrial construction. Other supply-and-demand indicators, such as construction rates for new office and commercial buildings and the continuing trend to construct larger homes with more rooms, also suggest that the gypsum industry will be close to the same level as in 2005.

The availability of more FGD gypsum will continue to increase as scrubbers come online at more and more coal-fired electric powerplants (U.S. Environmental Protection Agency, 2003§). During the next several years, the use of mined gypsum may decline in the United States as greater quantities of synthetic gypsum are used in wallboard manufacturing. Some actual and planned gypsum mine closings already have been attributed to substitution by synthetic gypsum. This rate of substitution could accelerate additional mine closings during the rest of this decade. However, only those FGD plants that are near enough to wallboard plants to have a transportation advantage will be able to have their gypsum output used in the near future. The percentage of synthetic gypsum use may eventually reach an economic equilibrium point. In the long term, as disposal areas fill and opening new disposal sites becomes more difficult, power companies may have to calcine and clean the gypsum waste slurry that they produce and may even have to subsidize transportation costs to rid themselves of excess gypsum waste. This may increase the economic viability of using FGD gypsum from powerplants that may have been considered too far from wallboard plants in the past.

Expansion of synthetic gypsum resources will continue in Europe and North America, but would be limited by the diminishing number of coal-fired electric powerplants without FGD systems. Most domestic powerplants built in recent years have been natural-gas fired. The trend towards using FGD gypsum as a raw material at the expense of natural gypsum is set to continue as air pollution regulations spread across the globe to include developing nations. In Europe, 16 Mt of FGD gypsum was produced, and there were 74 gypsum factories using FGD gypsum as a raw material (Slatten, 2005).

The U.S. gypsum industry has been moving toward the use of large-capacity wallboard plants supplied from multiple sources, including synthetic gypsum from coal-fired powerplants. These larger wallboard plants have been located in regions of high population and growth, which are the areas of highest consumption. The older, less efficient and smaller, natural (mined) gypsum-fed plants will find it increasingly difficult to compete, and some will close (Harris, 2001).

As a response to increased public awareness, the gypsum industry probably will increase its recycling of scrap materials into raw materials streams. There also will be an increase in the use of ecolabels, such as the Scientific Certification System Green Cross, which certifies there is recycled and recovered content in each product. Implementation of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, Public Law 109-59 (SAFETEA-LU), which was passed by congress and signed by the President in August of 2005, will continue funding for the building and repair of the Nation's highway system through 2009 (U.S. Department of Transportation, Federal Highway Administration, 2006§). This will be an important stimulus for the domestic cement industry and, thus, will increase the demand for gypsum as an integral component of cement.

Industry trends also indicate significant developments abroad in the coming decade. For example, the pace and magnitude of wallboard plant construction in Asia, particularly China and Thailand, indicated that this region, with billions of potential consumers, could become one of the world's leading gypsum wallboard markets. The gypsum market in Japan will probably also grow at increasing rates. Future demand in emerging Asian markets is likely to be an important factor in gypsum sector growth (Industrial Minerals, 2004).

Elsewhere, wallboard production capacity growth and the recognition of the convenience and economy of wallboard as a building material in Central America, Europe, India, and South America suggests that wallboard manufacturing will require increased production of gypsum in the future.

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TABLE 1
SALIENT GYPSUM STATISTICS[1]

(Thousand metric tons and thousand dollars)

	2001	2002	2003	2004	2005
United States:					
Crude:					
Production:					
Quantity	16,300	15,700	16,700	17,200	21,100
Value	119,000	108,000	114,000	124,000	158,000
Imports for consumption	8,270	7,970	8,300	10,100	11,200
Synthetic gypsum sales	6,820	9,900	8,300	8,400 r	8,690
Calcined:					
Production:					
Quantity	19,100	18,600	20,400	23,200	21,000
Value	352,000	372,000	400,000	489,000	426,000
Products sold, value	2,470,000	2,690,000	2,880,000	3,160,000	3,480,000
Exports, value	96,400	102,000	111,000	127,000	142,000
Imports for consumption, value	231,000	196,000	184,000	231,000	288,000
World, production	105,000	107,000 r	110,000 r	112,000 r	118,000 e

eEstimated. rRevised.

[1]Data are rounded to no more three significant digits.

TABLE 2
CRUDE GYPSUM MINED IN THE UNITED STATES, BY STATE[1]

	2004			2005		
State	Active mines	Quantity (thousand metric tons)	Value (thousands)	Active mines	Quantity (thousand metric tons)	Value (thousands)
Arizona and New Mexico	4	619	$4,340	5	701	$5,300
Arkansas, Kansas, Louisiana	4	2,250	23,100	6	3,400	34,200
California, Nevada, Utah	10	4,170	22,100	11	4,690	29,900
Colorado, South Dakota, Wyoming	5	934	6,420	4	1,080	7,750
Indiana, New York, Ohio, Virginia	2	1,150	8,000	3	3,430	19,800
Iowa	6	1,920	14,600	5	2,610	20,100
Michigan	2	452	5,660	3	1,050	10,700
Oklahoma	5	3,250	20,800	4	2,620	18,400
Texas	6	2,450	18,800	4	1,540	11,800
Total	44	17,200	124,000	45	21,100	158,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 3
CALCINED GYPSUM PRODUCED IN THE UNITED STATES, BY STATE[1]

State	2004 Active plants	2004 Quantity (thousand metric tons)	2004 Value (thousands)	2005 Active plants	2005 Quantity (thousand metric tons)	2005 Value (thousands)
Alabama	1	554	$15,800	1	518	$17,400
Arizona, Colorado, New Mexico, Utah	3	849	11,200	3	831	9,860
Arkansas, Louisiana, Oklahoma	6	2,950	52,800	5	1,770	30,200
California	7	2,510	51,400	5	2,220	45,300
Maryland, North Carolina, Virginia	4	1,240	32,800	3	1,010	31,400
Florida	3	1,510	36,800	3	1,260	35,000
Georgia	2	481	9,000	2	589	10,800
Illinois, Indiana, Kansas	6	2,030	39,800	6	2,170	44,300
Iowa	5	1,930	28,500	5	2,590	26,200
Massachusetts, New Hampshire, New Jersey	5	1,430	35,100	5	1,380	40,000
Michigan	4	916	16,900	3	502	12,600
Nevada	2	1,410	9,970	3	1,450	18,300
New York	3	2,130	29,200	2	752	21,700
Ohio	2	223	4,410	2	235	4,730
Oregon	1	492	14,800	1	581	18,400
Pennsylvania	1	585	13,900	1	600	14,600
Texas	5	1,470	27,300	5	1,830	34,500
Washington and Wyoming	2	487	59,000	3	737	10,500
Total	62	23,200	489,000	58	21,000	426,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 4
GYPSUM PRODUCTS (MADE FROM DOMESTIC, IMPORTED, AND SYNTHETIC GYPSUM) SOLD OR USED IN THE UNITED STATES, BY USE[1]

(Thousand metric tons and thousand dollars)

Use	2004 Quantity	2004 Value	2005 Quantity	2005 Value
Uncalcined:				
Portland cement	3,160	41,100	2,750	39,500
Agriculture and miscellaneous[2]	1,030	29,300	1,160	30,500
Total	4,180	70,500	3,920	70,000
Calcined:				
Plasters	906	143,000	892	149,000
Prefabricated products[3]	29,500	2,940,000	27,300	3,260,000
Total calcined	30,400	3,090,000	28,200	3,410,000
Grand total	34,600	3,160,000	32,100	3,480,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes synthetic gypsum.
[3]Includes weight of paper, metal, or other materials and some synthetic gypsum.

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TABLE 5

PREFABRICATED GYPSUM PRODUCTS SOLD OR USED IN THE UNITED STATES[1]

Product	2004 Quantity (thousand square feet)	2004 Quantity[2] (thousand metric tons)	2004 Value (thousands)	2005 Quantity (thousand square feet)	2005 Quantity[2] (thousand metric tons)	2005 Value (thousands)
Lath:						
3/8-inch	967	1	$340	767	487	$229
1/2-inch	2,350	2	509	1,420	1	331
Other	9,920	10	1,610	12,300	9	1,420
Total	13,200	13	2,450	14,500	11	1,980
Veneer base	452,000	462	51,200	429,000	442	52,600
Sheathing	268,000	270	32,300	186,000	182	25,000
Regular gypsumboard:						
3/8-inch	2,070,000	2,130	121,000	687,000	636	104,000
1/2-inch	13,500,000	11,800	1,330,000	13,300,000	11,500	1,520,000
5/8-inch	2,030,000	2,200	123,000	2,110,000	2,260	135,000
1-inch	551,000	600	60,100	211,000	228	54,200
Other[3]	963,000	1,000	103,000	1,150,000	1,210	121,000
Total	19,100,000	17,700	1,740,000	17,500,000	15,800	1,940,000
Type X gypsumboard	8,100,000	8,470	809,000	7,830,000	8,130	908,000
Predecorated wallboard	157,000	157	37,000	80,200	81	12,400
5/16-inch mobile home board	374,000	378	44,100	462,000	427	50,800
Water- and moisture-resistant board	1,720,000	1,730	168,000	1,740,000	1,760	186,000
Other	301,000	312	64,000	448,000	467	89,600
Grand total	30,500,000	29,500	2,940,000	28,700,000	27,300	3,260,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes weight of paper, metal, or other materials.

[3]Includes 1/4-, 7/16-, and 3/4-inch gypsumboard.

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TABLE 6
IMPORTS FOR CONSUMPTION OF CRUDE GYPSUM, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

Country	2004		2005	
	Quantity	Value	Quantity	Value
Austria	(2)	8	--	--
Bahrain	--	--	(2)	11
Brazil	--	--	17	155
Canada[3]	6,890	67,300	7,650	79,800
China	42	280	(2)	2
Costa Rica	(2)	13	--	--
Denmark	--	--	(2)	24
Dominica	--	--	(2)	13
Dominican Republic	149	1,100	166	1,290
France	(2)	6	(2)	20
Germany	2	8	(2)	50
Italy	27	37	(2)	3
Jamaica	40	538	64	434
Japan	(2)	6	--	--
Jordan	--	--	(2)	2
Mexico	2,250	20,000	2,500	21,500
Morocco	--	--	(2)	2
Netherlands	(2)	8	--	--
Peru	(2)	46	(2)	8
South Africa	7	672	--	--
Spain	728	7,250	782	10,600
Sweden	--	--	(2)	42
United Kingdom	(2)	20	(2)	9
Total	10,100	97,300	11,200	114,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

[3]Includes anhydrite.

Source: U.S. Census Bureau.

TABLE 7
U.S. GYPSUM AND GYPSUM PRODUCTS TRADE FOREIGN[1]

(Thousand metric tons and thousand dollars)

Year	Crude[2]		Plasters[3]		Boards[4]		Other, value[5]	Total, value
	Quantity	Value	Quantity	Value	Quantity	Value		
Exports:								
2004	149	15,000	332	31,800	83	51,100	29,300	127,000
2005	148	16,400	174	33,700	86	58,900	33,000	142,000
Imports for consumption:								
2004	10,100	97,200	5	3,420	617	87,100	43,200	231,000
2005	11,200	114,000	6	4,350	739	129,000	41,100	288,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Data are for "Gypsum, anhydrite," Harmonized Tariff Schedule of the United States (HTS) code 2520.10.0000.

[3]Data are for "Plasters," HTS code 2520.20.0000.

[4]Data are for "Boards, sheets, panels, tiles, and similar articles, not ornamented—Faced or reinforced with paper or paperboard only," HTS code 6809.11.0000.

[5]Data are for "Boards, sheets, panels, tiles, and similar articles, not ornamented: Other," HTS code 6809.1900.00, and "Other articles," HTS code 6809.90.0000.

Source: U.S. Census Bureau.

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TABLE 8

GYPSUM: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country	2001	2002	2003	2004	2005[e]
Afghanistan[e]	3	3	3	3	2
Algeria	281	322	350	1,058 [r]	1,460 [3]
Argentina	372	366 [r]	490 [r]	673 [r]	700
Australia[e]	3,800	4,000	4,000	4,000	4,000
Austria[e, 4]	1,000	1,000	1,000	1,000	1,000
Azerbaijan[e]	1	1	4 [3]	4	5
Bhutan[e]	55	55	56	56	57
Bosnia and Herzegovina[e]	30	30	30	30	30
Brazil[4]	1,507	1,633 [r]	1,529 [r]	1,472 [r]	1,480 [3]
Bulgaria[4]	167	156	168	170 [e]	160
Burma	65	90	66	71 [r]	71
Canada[4]	7,821	8,809	8,376	9,339	9,400 [3]
Chile	517	610	662	630 [r]	630
China[e]	6,800	6,850	6,850	7,000	7,300
Colombia[e]	560	560	560	560	700
Croatia	131	145	166	150	150
Cuba[e]	130	130	130	130	130
Cyprus	250	295	300	255 [r]	260
Czech Republic	24	102	104	100 [e]	100
Dominican Republic	176 [r]	163	240 [r]	459 [r]	460
Ecuador	1	5	5	5 [e]	5
Egypt[e, 4]	2,000	2,000	2,000	2,000	2,000
El Salvador[e]	6	6	6	6	6
Eritrea	1	1	1	1	1
Ethiopia[4]	51	23 [r]	48	51 [r]	52
France[e, 4]	4,500	3,500	3,500	3,500	3,500
Germany, marketable[4]	1,966 [r]	1,761	1,748	1,579 [r]	1,580
Greece[e, 4]	600	500	500	500	500
Guatemala	97	81	67	106 [r]	100
Honduras	60	60	60	60 [e]	60
Hungary[e, 4]	252	72	75	75	70
India[e]	2,250	2,300	2,300	2,350	2,400
Indonesia	6	6	6	6	6
Iran[5]	10,382 [r]	13,535 [r]	13,828 [r]	12,594 [r]	13,000
Iraq[6]	NA	NA	NA	NA	NA
Ireland[e]	450	450	450	450	450
Israel	70 [r, e]	14 [r]	65 [r]	76 [r]	79
Italy[e]	1,300	1,300	1,200	1,200	1,210
Jamaica	320	165	249	283 [r]	285
Japan	5,874	5,645	5,764	5,865 [r]	5,890
Jordan	86	11	64	135 [r]	140
Kenya[4]	8	8 [r]	9 [r]	9 [r]	9
Laos	121	110	102	244 [r]	250
Latvia	125 [e]	217	159	226 [r]	220
Lebanon[e]	2	2	2	2	2
Libya[e]	150	150	150	175 [r]	175
Luxembourg[e, 4]	(7)	(7)	(7)	(7)	(7)
Macedonia[e]	20	20	20	20	20
Mali[e]	1	1	1	1	1

See footnotes at end of table.

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TABLE 8—Continued
GYPSUM: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country	2001	2002	2003	2004	2005[e]
Mauritania	100 [e]	100 [e]	34 [r]	39 [r]	39
Mexico[4]	6,237	6,740 [r]	6,986	700 [e]	7,200
Moldova[e]	32	32 [3]	32	32	32
Mongolia[e]	25	25	25	25	25
Morocco[e]	550	600	600	600	600
Nicaragua[4]	34	28	31	30 [r]	30
Niger	3	18	18	18 [e]	18
Nigeria[e]	610 [3]	300	100	100	100
Oman	44	56	50 [e]	60 [e]	60
Pakistan[e]	350	360 [3]	360	360	360
Paraguay[e]	4 [3]	4	5 [r]	5 [r]	5
Peru	21	75	71	150	150 [p]
Poland[4]	1,094	1,147	1,328	1,272	1,300
Portugal[e, 4]	500	500	500	500	500
Romania	275	421	394	350 [e]	350
Russia[e]	1,500 [r]	1,600 [r]	1,800 [r]	2,077 [r, 3]	2,200
Saudi Arabia[e]	450	450	450	450	450
Serbia and Montenegro	58	55	55	55 [e]	50
Sierra Leone[e]	4	4	4	4	4
Slovakia[4]	169	122	125	125 [e]	125
Slovenia[e]	10	10	10	10	10
Somalia	NA [r]	NA [r]	NA [r]	NA [r]	NA
South Africa	383	422 [r]	394	452 [r]	548 [p, 3]
Spain[4]	11,909	11,218	11,500 [e]	11,500 [e]	11,500
Sudan[e, 4]	2	5	13 [r, 3]	14 [r]	14
Switzerland[e]	300	250	250	250	250
Syria	290	351	375 [e]	375 [e]	375
Taiwan	1	--	--	--	--
Tajikistan[e]	35	35	35	35	35
Tanzania[4]	72	73 [r]	33 [r]	59 [r]	23 [p]
Thailand	6,191	6,326	7,291	7,169 [r]	6,920
Tunisia[e]	125	125	110	130 [r]	130
Turkey	329	264	197	250 [r]	250
Turkmenistan[e]	100	100	11	100	100
Uganda	--	"(7)	"(7)	"(7)	"(7)
United Arab Emirates[e]	90	90	100	100	100
United Kingdom[e, 4]	1,500	1,500	1,500	1,500	1,500
United States[8]	16,300	15,700	16,700	17,200	21,100 [3]
Uruguay[e]	1,127 [3]	1,130	1,130	1,130	1,130
Venezuela	5	-- [r]	-- [r]	-- [r]	10
Yemen	44	41	42	44 [e]	44
Zambia	-- [r]	-- [r]	-- [r]	-- [r]	--
Total	10,500	107,000 [r]	110,000 [r]	112,000 [r]	118,000

See footnotes at end of table.

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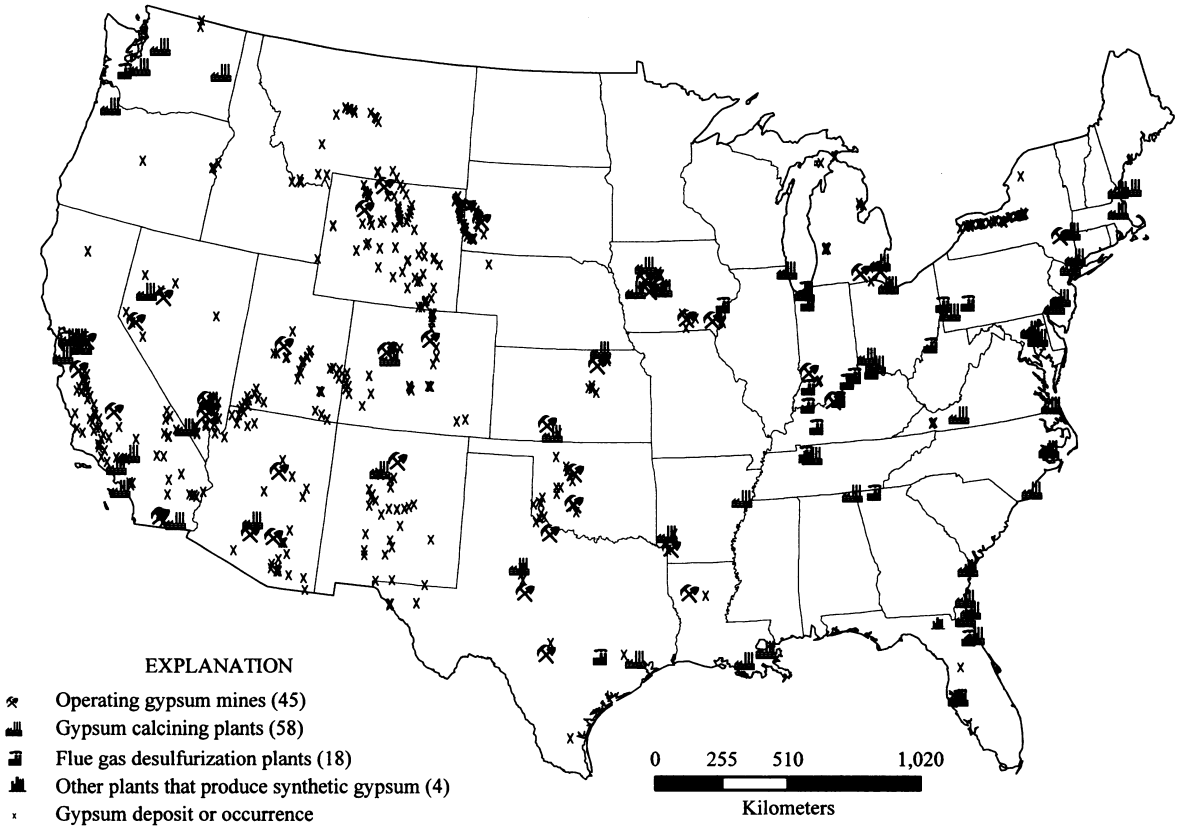
TABLE 8—Continued
GYPSUM: WORLD PRODUCTION, BY COUNTRY[1, 2]

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available. --Zero.
[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]Table includes data available through July 15, 2006.
[3]Reported figure.
[4]Includes anhydrite.
[5]Data are for years beginning March 21 of that stated.
[6]Iraq may also produce gypsum, but definitive information on output levels, if any, is not available.
[7]Less than ½ unit.
[8]Excludes byproduct gypsum.

FIGURE 1
GYPSUM MINES, PLANTS, AND OCCURRENCES IN THE CONTERMINOUS UNITED STATES IN 2005



Sources: USGS survey, 2005; Withington, C.F., 1962, Gypsum and anhydrite in the United States (exclusive of Alaska and Hawaii): U.S. Geological Survey Minerals Investigation Resource Map MR-33, scale 1:3,168,000.

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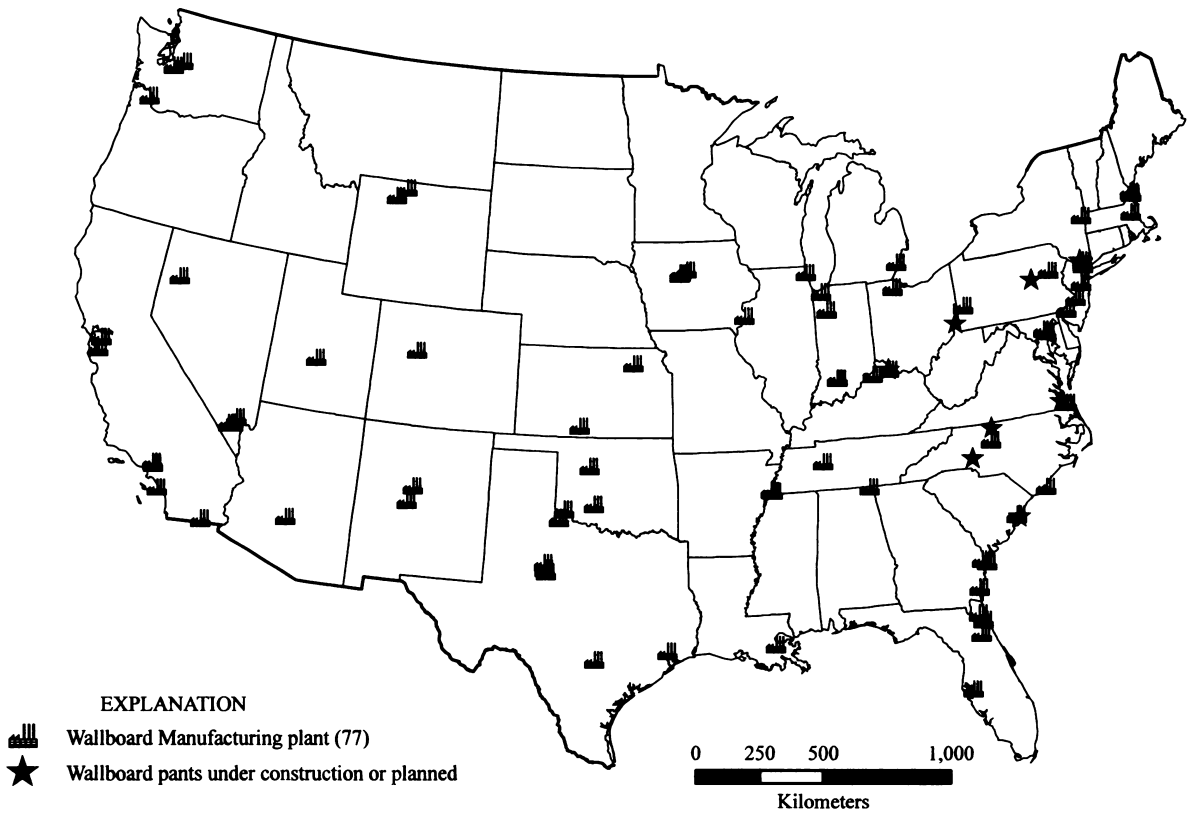
FIGURE 2
WALLBOARD MANUFACTURING PLANTS IN THE UNITED STATES



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HELIUM

By Norbert Pacheco[1]

Sales of Grade-A helium (99.995% or greater purity) by private industry were 81.6 million cubic meters[2] (2.94 billion cubic feet) in the United States in 2005, and exports by private producers were 51.4 million cubic meters (1.85 billion cubic feet) for total sales of 133 million cubic meters (4.80 billion cubic feet) of U.S. helium, a 2.3% increase from 2004 (table 1). During 2005, domestic helium sales decreased by 4.1%, and helium exports increased by 14.5% compared with those of 2004.

Legislation and Government Programs

On October 9, 1996, the President signed the Helium Privatization Act of 1996 (Public Law 104-273). This legislation directed the Federal Helium Program to discontinue production and sale of refined helium by April 9, 1998. The Government's Exell helium plant was shut down in March 1998, and all components of the legislation were implemented as directed by the Act. Only one of the key components of this legislation is pending completion. The transfer of the Landis Property to the Texas Plains Girl Scout Council has been completed. The General Services Administration (GSA) is currently in the process of screening and disposal of the Amarillo Plant per Federal property management regulations. The environmental cleanup at the Exell helium plant is in progress with an expected completion date of June 30, 2006. Final documents will then be submitted to the Texas Commission on Environmental Quality (TCEQ) for the certificate of completion (COC). Upon receipt of the COC, the GSA will begin the disposal process.

Production

Domestic production data for helium were developed by the U.S. Bureau of Land Management (BLM) from records of its own operations as well as from its own high-purity helium survey, an annual voluntary canvass of private U.S. operations. Of the eight operations to which a survey request was sent, all responded, and those data plus data from BLM operations represent 100% of the total helium sales and recovery data listed in table 3.

In 2005, 13 companies operated 18 of 21 privately owned domestic helium plants, 13 of which extracted helium from natural gas (table 2). Two of the crude helium plants and one helium purification plant did not produce or extract helium during 2005. All but two extraction plants used cryogenic extraction processes. The total sales of U.S.-produced helium increased by 2.3% compared with those of 2004. All natural gas processed for helium recovery came from gasfields in Colorado, Kansas, Oklahoma, Texas, Utah, and Wyoming (fig. 1). During 2005, 10 private plants purified helium by using pressure swing adsorption technology. Nine privately owned plants that produced Grade-A helium also liquefied helium

Domestic measured helium reserves and indicated helium resources as of January 1, 2003, were estimated to be 8.5 billion cubic meters (305 billion cubic feet). The resources included measured helium reserves estimated to be 3.7 billion cubic meters (133 billion cubic feet) in natural gas from which helium is being extracted. The measured reserves included nearly 867 million cubic meters (31.2 billion cubic feet) of helium stored by the BLM in the helium storage conservation system. Measured helium reserves from indicated resources of natural gas with helium content greater than 0.05% were estimated to be 1.8 billion cubic meters (65 billion cubic feet). Indicated helium resources, a category slightly less certain than measured reserves, in natural gas with less than 0.3% helium were estimated to be 3.0 billion cubic meters (107 billion cubic feet). The majority of these indicated reserves were derived from the Potential Gas Committee designation of unconfirmed/probable reserves (Curtis, 2002). Approximately 2.5 billion cubic meters (91 billion cubic feet), or 98% of federally owned helium, is located in the Riley Ridge area in Wyoming and the Cliffside field in Texas.

Most domestic helium resources are in the Midcontinent and Rocky Mountain regions of the United States. The measured helium reserves are in approximately 102 gasfields in 11 States. Of these reserves, 98% is contained in the Hugoton field in Oklahoma, Kansas, and Texas; the Panoma field in Kansas; the Keyes field in Oklahoma; the Panhandle West and Cliffside fields in Texas; and the Riley Ridge area in Wyoming. During 2005, the BLM analyzed 100 natural gas samples from 11 States in conjunction with its program to survey and identify possible new sources of helium.

Consumption

In 2005, private industry supplied 100% of domestic helium demand. The major domestic end uses of helium were cryogenics (28%), pressurizing and purging (26%), welding (20%), and controlled atmospheres (13%). Other uses included chromatography/lifting gas/heat transfer (7%), leak detection (4%), and synthetic breathing mixtures (2%) (fig. 3). Cryogenics, specifically magnetic resonance imaging applications, dominated liquid helium use. Estimated 2005 domestic consumption by end use was based on a 2003-04 end-use survey conducted by BLM's Helium Operations to determine trends in helium usage.

In-kind crude helium sales regulations (43 CFR part 3195), which became effective on November 23, 1998, required helium

[1]Team Leader, Resources Evaluation, U.S. Bureau of Land Management, Amarillo Field Office—Helium Operations, Amarillo, TX.

[2]All metric helium volumes herein are at 101.325 kilopascals absolute (14.696 pounds per square inch absolute) and 15° C (59° F). Helium volumes, reported in parentheses following metric units, are measured in cubic feet at 14.7 pounds per square inch absolute and 70° F—1,000 cubic feet (14.7 pounds per square inch absolute and 70° F) equals 27.737 cubic meters (101.325 kilopascals absolute and 15° C) and 1 cubic meter (101.325 kilopascals and 15° C) equals 36.053 cubic feet (14.7 pounds per square inch absolute and 70° F).

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refiners that sell helium to Federal agencies and their contractors to buy an equivalent amount of crude helium from the BLM. Such sales are referred to as "in-kind crude helium sales." In 2005, in-kind crude helium sales were 6.6 million cubic meters (236 million cubic feet). The sales were made to eight companies through contracts with the BLM.

Stocks

The volume of helium stored in the BLM helium conservation storage system, including the conservation pipeline network and the Cliffside field, totaled 731 million cubic meters (26 billion cubic feet) on December 31, 2005. The storage system contained crude helium purchased under contract by the BLM from 1962 to 1973 and privately owned helium extracted by industry from natural-gas-supplying fuel markets and stored under contract. This privately owned helium is returned to the owners as needed for purification to supply private demand. During 2005, 17.0 million cubic meters (611 million cubic feet) of private helium was delivered to the BLM's helium conservation system, and 74.1 million cubic meters (2.67 billion cubic feet) was withdrawn for a net decrease of 57.1 million cubic meters (2.06 billion cubic feet) of private helium in storage (table 4).

Transportation

Private producers and/or distributors shipped helium, predominantly as a liquid, in semitrailers, which delivered the liquid helium to distribution centers where some of it was gasified and compressed into trailers and small cylinders for delivery to end users. The remaining liquid helium was sold as bulk liquid or repackaged in dewars of various sizes for delivery.

Prices

In fiscal year 2005, the price that the BLM charged private companies for in-kind crude helium sales was $1.965 per cubic meter ($54.50 per thousand cubic feet).

Foreign Trade

In 2005, exports of Grade-A helium increased by 14.4% to 51.4 million cubic meters (1.85 billion cubic feet) compared with those of 2004 and accounted for 39% of sales of U.S.-produced helium; private industry supplied all U.S. helium exports (table 1). The increase in helium exports is attributed to increased demand for helium from Australia, China, Japan, the Republic of Korea, Mexico, Taiwan, and United Kingdom. Of the helium exported from the United States, 54% went to Asia, with Japan receiving 24% of total exports. Of the exported helium, 23% was shipped to Europe; collectively, Belgium, France, Germany, and the United Kingdom received 93% of the helium exported to Europe. Other exports were as follows: Canada and Mexico, 10%; Australia and New Zealand, 5%; South America, 4%; the Middle East, 2%; Africa, 1%; and Central America and the Caribbean, less than 1% each. Import tariffs on helium established on January 1, 1998, remained at the 3.7% rate for normal trade relations (NTR) nations and 25% for non-NTR nations.

World Review

Excluding the United States, world production capacity of helium in 2005 increased to an estimated 46 million cubic meters (1.65 billion cubic feet) (table 5). The increased capacity comes from a new production facility at Qatar and an expansion project in Algeria. The Skikda, Algeria, helium expansion project has added at least 8.3 million cubic meters (300 million cubic feet) of new production, and the new helium extraction facility at Qatar added 8.3 million cubic meters (300 million cubic feet) to the global helium market. All known helium produced outside the United States in 2005 was extracted in Algeria, Poland, Qatar, and Russia.

Outlook

In 2005, total market sales for U.S.-produced helium increased by 2.3% compared with those of 2004. From 2000 to 2005, the market growth rate was 1% per year, while from 1995 to 2005, the market growth rate was 3.3% per year. Sales of U.S.-produced helium again were expected to increase by 2% to 3% for 2006. With the problems encountered in transporting the new helium production from Algeria and Qatar, demand for exports of helium produced in the United States is expected to rise again in 2006. U.S. exports of helium in 2006 will be determined by demand for helium from overseas, which has increased during the past 3 years.

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TABLE 1
TOTAL SALES OF GRADE-A HELIUM PRODUCED IN THE UNITED STATES[1]

(Million cubic meters)

Year	Domestic sales	Exports[2]	Total sales
2001	89.0	43.0	132
2002	87.6	39.5	127
2003	80.8	41.3	122
2004	85.1	44.9	130
2005	81.6	51.4	133

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Source: U.S. Census Bureau.

TABLE 2
OWNERSHIP AND LOCATION OF HELIUM EXTRACTION PLANTS IN THE UNITED STATES IN 2005

Owner or operator	Location	Product purity
Air Products and Chemicals, Inc.	Hansford County, TX	Grade-A helium.[1]
Do.	Liberal, KS	Do.
SemKan L.P.[2]	Dodge City, KS	Crude helium.
BOC Gases	Otis, KS	Grade-A helium.[1]
BP America Inc.	Sunray, TX	Crude helium.
Do.	Ulysses, KS	Do.
Midstream Energy Services, LLC[3]	Keyes, OK	Crude and Grade-A helium.[1]
K-L Energy Partners LLC[4]	Lakin, KS	Crude helium.
Duke Energy Field Services	Cheyenne Wells, CO	Crude and Grade-A helium.[1]
Do.	Hansford County, TX	Crude helium.
Do.	Liberal, KS	Do.
Do.	Borger, TX	Do.
Exxon Mobil Corp.	Shute Creek, WY	Crude and Grade-A helium.[1]
Newpoint Gas Services, Inc.[5]	Shiprock, NM	Grade-A helium.
ONEOK, Inc.[5]	Bushton, KS	Crude helium.
Do.[6]	Scott City, KS	Do.
Pioneer Natural Resources Co.	Fain, TX	Do.
Do.	Satanta, KS	Do.
Praxair, Inc.	Bushton, KS	Grade-A helium.[1]
Do.	Ulysses, KS	Do.
EnCana Oil & Gas (USA) Inc.[7]	Moab, UT	Crude and Grade-A helium.[1]

[1]Including liquefaction.
[2]SemKan L.P. purchased plant from BCCK Engineering Inc. in November 2004. Plant did not produce any helium during 2005.
[3]Midstream Energy Services, LLC purchased plant from Nathaniel Energy in March 2006.
[4]K-L Energy Partners, LLC. purchased plant from Regency Gas Services, LP in early 2005.
[5]Plant did not produce any helium during 2005.
[6]Output is piped to Ulysses, KS, for purification.
[7]EnCana Oil & Gas (USA) Inc. purchased plant from Tom Brown, Inc. in late 2004.

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TABLE 3
HELIUM RECOVERY IN THE UNITED STATES[1]

(Thousand cubic meters)

	2001	2002	2003	2004	2005
Crude helium:					
Bureau of Land Management (BLM) sold (in-kind and open market)	--	--	51,800	29,300	41,400
Private industry:					
Private helium accepted and stored by BLM[1]	18,000	16,600	19,400	19,100	17,000
Helium withdrawn from storage	-62,900	-56,300	-54,500	-63,100	-74,100
Total net helium put into storage	-44,900	-39,700	-35,100	-44,000	-57,100
Grade-A helium:					
Private industry sold	131,900	127,100	122,000	130,000	133,000
Total helium stored	-44,900	-39,700	-35,100	-44,000	-57,100
Helium recovery from natural gas	87,000	87,400	86,900	86,000	75,900

-- Zero.

[1]Negative numbers denote a net withdrawal from BLM's underground storage facility, a partially depleted natural gas reservoir at the Cliffside field near Amarillo, TX.

TABLE 4
SUMMARY OF BUREAU OF LAND MANAGEMENT HELIUM CONSERVATION STORAGE SYSTEM OPERATIONS[1, 2]

(Thousand cubic meters)

	2003	2004	2005
Helium in conservation storage system on January 1:			
Stored under BLM conservation program[3]	822,000	770,000	741,000
Stored for private producers under contract	45,000	62,000	47,000
Total[3]	867,000	832,000	788,000
Input to system:			
Net deliveries from BLM plants	--	--	--
Stored for private producers under contract	19,400	19,100	17,000
Total[3]	19,400	19,100	17,000
Redelivery of helium stored for private producers under contract	-54,500	-63,100	-74,100
Net addition to system[3]	-35,100	-44,000	-57,100
Helium in conservation storage system on December 31:			
Stored under BLM conservation program[3]	770,000	741,000	699,000
Stored for private producers under contract	62,000	47,000	32,000
Total[3]	832,000	788,000	731,000

-- Zero.

[1]Crude helium is injected into or withdrawn from BLM's underground storage facility, a partially depleted natural gas reservoir at the Cliffside field near Amarillo, TX.

[2]Negative numbers denote a net withdrawal from BLM's storage facility.

[3]Net additions to system do not include in-kind crude sales or transfers. Totals, however, do include crude sales and transfers.

TABLE 5
WORLD GRADE-A HELIUM
ANNUAL PRODUCTION CAPACITY
AS OF DECEMBER 31, 2005

(Million cubic meters)

	Capacity
United States[1]	152
Rest of world[e]	46
Total[e]	198

[e]Estimated.

[1]Includes plants on standby as well as operating plants.

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FIGURE 1
MAJOR U.S. HELIUM-BEARING NATURAL GAS FIELDS

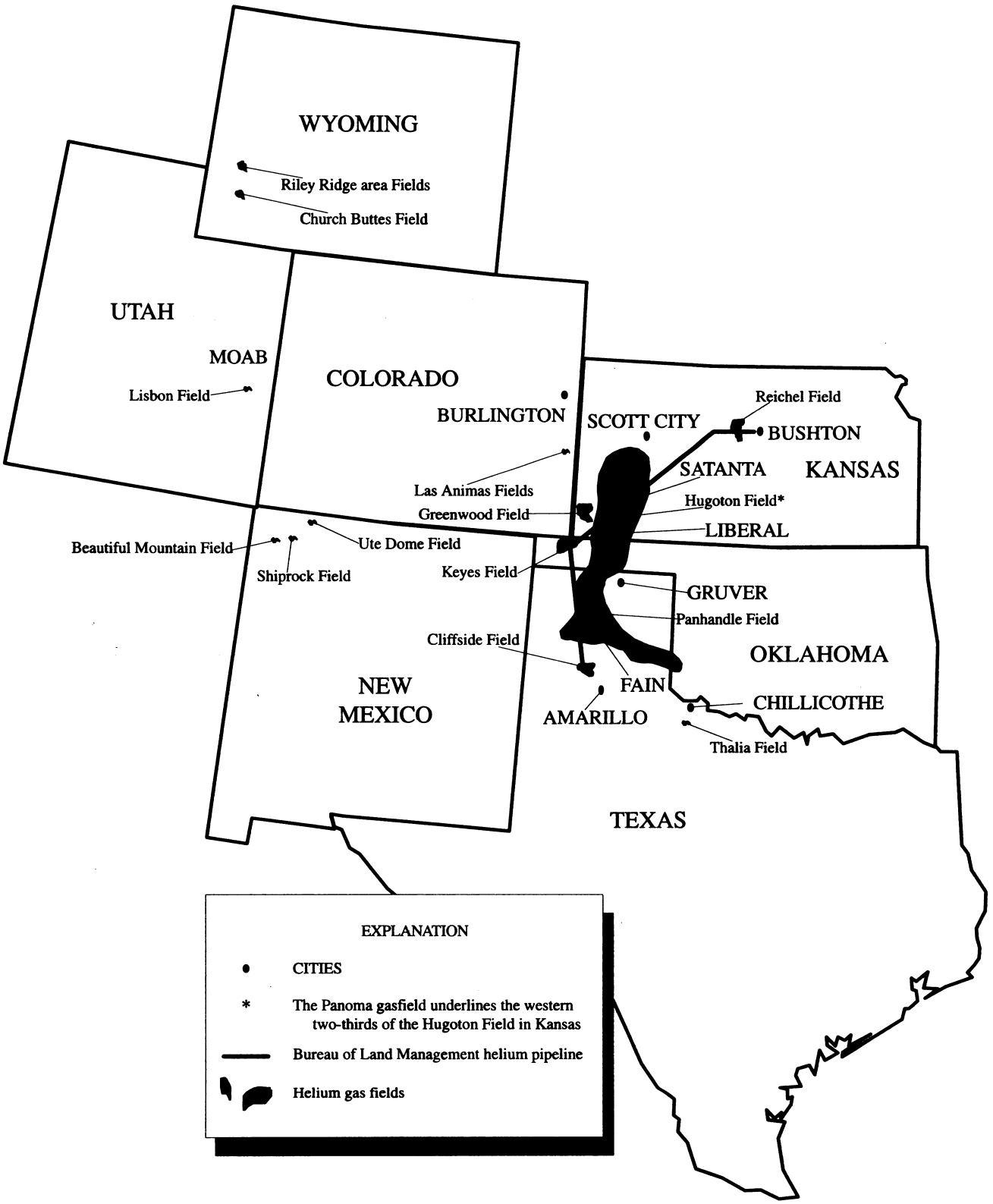

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FIGURE 2
HELIUM RECOVERY IN THE UNITED STATES

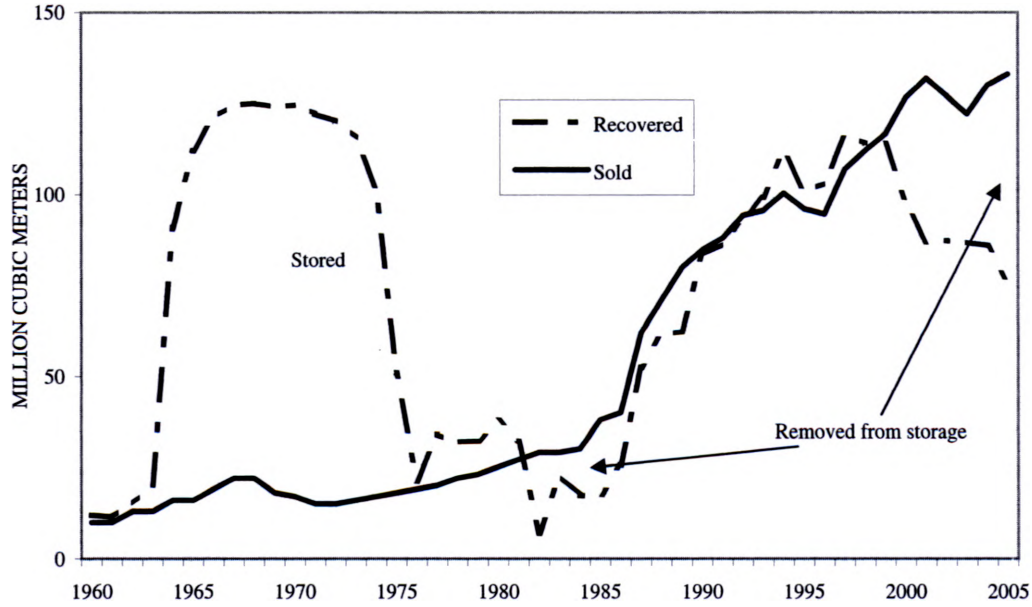
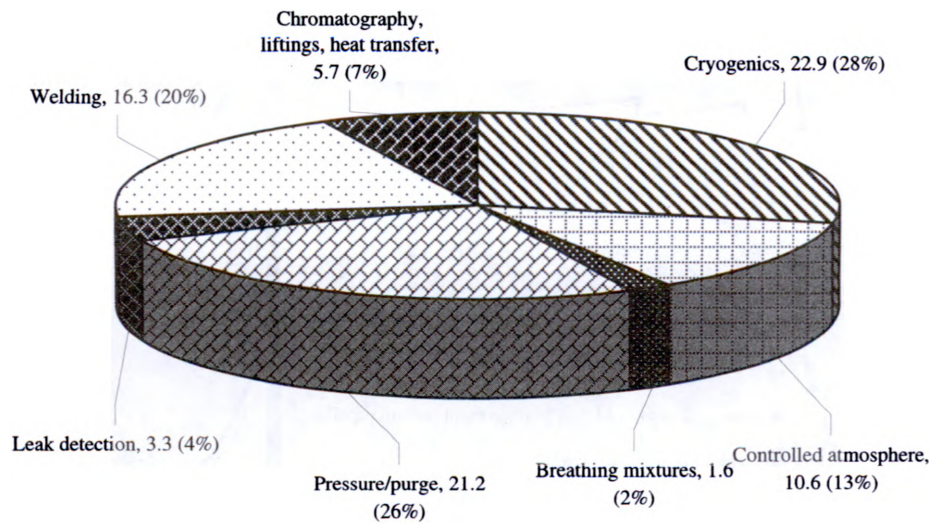


FIGURE 3
ESTIMATED HELIUM CONSUMPTION, BY END USE, IN THE UNITED STATES IN 2005[1]

(Million cubic meters)



[1]Total helium used in the U.S. in 2005 was estimated to be 81.6 million cubic meters.

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INDIUM

By Robert M. Callaghan and James F. Carlin, Jr.

Domestic survey data and table were prepared by Hoa P. Phamdang, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

All refined indium production in the United States during 2005 came from the refining of lower grade imported indium metal and from refining of scrap. Two refineries, one in New York and the other in Rhode Island, produced the majority of indium metal and indium compounds in 2005. A number of small companies produced specialty indium alloys and other indium products.

Domestic consumption of indium in 2005 was estimated by the U.S. Geological Survey to have remained stable at about 100 metric tons (t), based on import levels of unwrought indium and indium powder. Domestic consumption distribution for 2005 was estimated to be 70% for coatings, 12% for solder and alloys, 12% for electrical components and semiconductors, and 6% for other uses. The value of indium consumed in the United States in 2005 was about $90 million at an average New York, NY, dealer price of $816 per kilogram, as calculated from prices published in Platts Metals Week.

World primary refined production increased by 25%, compared with production in 2004. Most of the increase was attributed to China, with 59% of world production in 2005 compared with 49% in 2004. The other two major producing countries of refined indium recovered from domestic or imported concentrates or residues were Japan, with 14%, and Canada, with 10% of world production. Several other countries in Europe and one in South America produced smaller quantities (table 2). Higher prices for indium in 2005 spurred increased recycling activity as well.

World consumption increased owing to a continuation of strong demand for consumer electronics such as laptop computers, flat-panel televisions, and other devices containing flat-panel displays (FPDs) such as cell phones, as well as growth in the use of other technologies that used indium-tin oxide (ITO) coatings and indium metal. While some indium is used in electronic components such as capacitors, the bulk of the indium is used in the FPDs, either in liquid crystal displays (LCDs) or plasma display panels (PDPs) that contain ITO coatings. The continued popularity of larger sized monitors and televisions and their decreasing cost to consumers also contributed to the higher consumption levels.

Production

Though zinc was mined domestically, indium was apparently not recovered at U.S. zinc smelters. Production of indium in 2005 consisted of upgrading imported indium metal and powder. Lower grade (99.97%) and standard-grade (99.99%) imported indium was refined to purities of up to 99.99999%. Indium Corporation of America, Utica, NY, and Umicore Indium Products, Providence, RI (a division of n.v. Umicore, s.a., Olen, Belgium), accounted for the major share of U.S. production of indium metal and products.

Indium metal is sold in various forms (ingot, foil, powder, ribbon, wire, and others) as well as different grades. Many small companies produced high-purity indium alloys, compounds, solders, ITO coatings, and other indium products.

Small amounts of new indium scrap were recycled in 2005, as has been the case in recent years. Unlike some Asian countries, where substantial amounts of indium are recycled, there was no well developed infrastructure for collection and consumption of indium-containing scrap and waste in the United States. One of the problems with recycling is its cost; California addressed the issue with its 2003 Electronic Waste and Recycling Act (California Senate Bill 20), which banned the disposal of televisions and computer monitors in landfills, and in July 2005, began including LCD screens in a program requiring FPD purchasers to pay a fee to cover the cost of recycling (Adrian, 2005).

Consumption

The use of indium in coatings, which was mainly in the form of indium oxide and ITO, constituted almost three-quarters of total domestic indium use in 2005. The major use for these coatings was for thin-film coatings on glass and on FPDs. The use of ITO in organic light-emitting diodes (LEDs) is a relatively small segment of indium's end uses, but it is expected to have continued strong growth during the next several years.

Indium coatings are valuable for three properties—electrical conductivity, transparency, and infrared reflectance. LCDs and PDPs for portable computer screens, television screens, video monitors, and watches, which were the major commercial applications, use electrically conductive transparent coatings. These coatings are also used to defog aircraft and locomotive windshields and to keep glass doors on commercial refrigerators and freezers frost-free. Indium coatings on window glass take advantage of indium's infrared reflective properties and limit the transfer of radiant heat through the glass. This property of indium can be used to heat and cool buildings more efficiently. With the increased cost of indium in 2005 came a decrease in the amount used in architectural glass.

The technologies of glass coatings and semiconductors have been the largest areas of research and development for indium during the past several years. Although coatings remained the most widespread use for indium, the production of electrical components and semiconductors is expected to remain an important use for indium during the next several years. Research into uses of indium in solar cells was also ongoing.

About one-eighth of the indium used was combined with other metals to form low-melting-point alloys and solders. The alloys find various applications such as in electrical fuses and fusible links and as gripping tools for the grinding of delicate

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materials. The advantages of indium-containing solders are that they have lower melting points, are more flexible over a wider temperature range, and inhibit the leaching of gold components in electronic apparatus.

Alkaline batteries used indium to prevent buildup of hydrogen gas within sealed battery casings. Indium was also used in semiconductors, including semiconductors in fiber optics. Other uses of indium included dental alloys, electrode-less lamps, mercury alloy replacements, nuclear control rods, phosphors, and white gold alloys.

Prices

After approximately tripling in 2004, the price of indium in 2005 reached peaks of more than $1,000 per kilogram before declining at yearend. The average New York dealer price range, as reported by Platts Metals Week, for 99.97%- to 99.99%-pure indium began the year at $850 to $920 per kilogram. In March and September, indium sold for the highest prices of the year, before declining to yearly lows of $830 to $880 per kilogram in December. However, according to Platts Metals Week, the Indium Corporation of America producer price increased from $800 to $965 in the beginning of the year, and stayed at that level through yearend.

Stockpiling out of concern for continued rising prices in 2004 was thought to be a reason for the leveling off of prices in 2005. Japanese ITO producers in particular were thought to hold large stocks of indium bought in the 2004-05 fiscal year (Metal-Pages, 2005b§[1]). This in addition to an unexpected slowing of increase in demand for LCDs led to the price dip at yearend (Roskill's Letter from Japan, 2006a). Consumers with contracts at relatively high prices did not want to buy large quantities in the spot market to prevent a price rebound (Metal-Pages, 2005d§). Factors that helped maintain the prices included speculation that China's indium export tax would be cut to 5% to 8% from 13%, which would have the effect of raising prices, and a yuan reevaluation added $10 to $20 per kilogram to the cost of indium (Metal Bulletin, 2005a, b).

The supply of indium-containing zinc ore remained a concern. Effects from the closure of the Metaleurop S.A., Paris, France, zinc refinery in Noyelles-Godault in 2003, which removed 60 metric tons per year (t/yr) of indium from the market, were expected to continue (Francis-Grey, 2005). However, these supply concerns, the closure of several indium smelters in China for environmental reasons, and the operation of others below capacity owing to power shortages did not cause enough concern in the market to change the relatively flat pricing in 2005.

World Review

Canada.—Falconbridge Ltd., Toronto, Ontario, continued as one of Canada's two indium refiners, through its Kidd Creek, Ontario, refinery. The other producer was Teck Cominco Ltd., at its Trail, British Columbia, smelter and refinery. Falconbridge and Teck processed indium materials that originated primarily in their own mines. In 2005, the idled #2 slag fuming furnace at Trail was put to use recycling electronic scrap, which was expected to add to the supply of recycled indium (Moore, 2006). Both companies experienced strikes, though they had limited impact on the indium market despite slightly lower 2005 production. Teck's Trail facility experienced an 11-week strike, which was followed by a 4-week strike at Falconbridge's Kidd Creek plant (Ryan's Notes, 2005b).

China.—The year began with power shortages in China resulting in temporarily reduced indium output. Zhuzhou Smelter, a 40-t/yr indium producer in Hunan Province, shut a zinc line that was expected to result in a 50% reduction in indium production. Other zinc smelters were affected as well; Guangxi, Sichuan, and Yunnan Provinces also had small and mid-sized zinc plants operating at reduced capacity (Platts Metals Week, 2005b). The power outages were not as severe as those in 2004 because China is in the process of upgrading its electrical grid. More than $12 billion was spent in 2005 on new powerplants and transmission lines; spending was expected to increase to almost $20 billion per year through 2010 (American Metal Market, 2006a).

In February, environmental issues resulted in the closing of most indium smelters in Hunan Province, except the Zhouzhou Smelter, owing to pollution of the Xiang River. Resulting concern over indium availability led to increasing prices (Francis-Grey and Teo, 2005). Eight smelters were permanently closed as a result of environmental issues (Teo, 2005b). In late summer, about 20 indium smelters and refineries in Guangdong Province closed for the same reason. It was thought that some of these were smelters that had relocated from Hunan Province. These smaller operations contributed only about 3 metric tons per month (t/mo) of indium; the larger smelters with pollution controls in place contributed about 20 t/mo from this area (Teo and Lee, 2005). In December, a larger operation, the Shaoguan Smelter, and some smaller operations were closed after an environmental incident involving the Beijiang River (Platts Metals Week, 2006).

For the year however, indium production increased; for example, Huludao Zinc increased indium production by 77% in 2005 compared with that in 2004 (Metal-Pages, 2006c§). Mengzi Mining and Smelting began construction of a 50-t/yr capacity indium smelter in Yunnan Province with production set to begin in summer 2006 (Teo, 2005a). Zhuzhou Smelter began trial runs of a new ITO plant that would have a 23-t/yr capacity when fully operational (Metal-Pages, 2006b§). The Hechi Jinhe Mining and Smelting Co. renovated a major zinc smelter in 2005, and in December, began trial runs of a new indium production line. The company obtained raw material from its mine in Guangxi Province; supplies of indium-rich concentrate were said to be sufficient from the area to supply the smelter (Metal-Pages, 2006a§).

Japan.—ITO production capacity was increased by all producers in Japan. Nikko Materials Co. Ltd. and Samsung Corning Co. Ltd. intended to double their capacities to 50 t/mo and 20 t/mo, respectively, by yearend; Mitsui Metal Mining planned an increase to 30 t/mo from 22 t/mo (Roskill's Letter from Japan, 2005b). The plans to increase ITO production were in response to expected increases in worldwide LCD and

[1]References that include a section mark (§) are found in the Internet References Cited section.

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PDP demand. Matsushita Electric Industrial Co., for example, announced plans to double output of PDPs in 2006, maintaining 2005 levels at 130,000 panels per month (Platts Metals Week, 2005c).

Japan was mostly dependent on imported indium for its ITO production. The Toyoha Mine, the last byproduct indium-producing mine in Japan, was expected to close permanently in 2006 owing to depletion of ore (Platts Metals Week, 2005d). Toho Zinc announced that as a result of high indium prices and expected increased demand it would resume 10- to 20-t/yr indium production at its Annaka zinc refinery in Gunma Prefecture (Roskill's Letter from Japan, 2005a). Indium purity would be about 90%, with production at full capacity in 2006 (Platts Metals Week, 2005a).

More emphasis was placed on recycling. The loss of production caused by the idling of Nikko Metal's Toyoha Mine in spring 2005 was offset by a 30% increase in indium recycled in 2005 (Roskill's Letter from Japan, 2006b). Dowa Mining Co. Ltd. increased its recycling capacity to 150 t/yr from 100 t/yr. This would bring the country's total recycling capacity to 350 t/yr by 2006 (Ryan's Notes, 2005c). Sharp Corporation developed a recycling system that can extract 95% of the indium in FPDs (Platts Metals Week, 2005a).

Korea, Republic of.—Korea Zinc Co. restarted an indium production line with a 34-t/yr capacity, with output used for LCDs produced by LG Phillips LCD and Samsung Electronics Corp. (Roskill's Letter from Japan, 2005b). Mitsui Mining and Smelting Co. Ltd. announced plans to build a 120-t/yr ITO processing plant in Gyeonggi Province in order to support their South Korean customer base and allow the company's Japanese and Taiwanese units to focus on the countries in which the factories are located, for increased efficiency (Metal Bulletin, 2005b).

Samsung Electronics announced that it was working on a new LCD production line at the Tangjeong complex in Chuncheong Province, with production expected in 2006. The Republic of Korea was one of the main producers of LCDs, especially for FPD units for computers, mobile phones, and televisions.

Current Research and Technology

Canon Inc. said it would start making organic light-emitting diode (OLED) displays in 2006 as part of a plan to bring more production of key parts in-house and lower procurement costs. The company planned to use OLED displays in its own digital cameras, camcorders, and printers as early as the second half of 2006, replacing LCDs. Canon uses about 20 million displays each year (Appliance Magazine, 2005§).

In December, Honda Motor Co. announced plans to construct a factory that will produce 27.5-megawatt (MW)-capacity copper-indium-gallium-selenium (CIGS) solar cells in the summer of 2006 at the site of a Honda manufacturing plant for lawnmowers and motorcycles in Kumamoto on the island of Kiushu. Honda planned to start CIGS production in October 2007, ramping up to full production as soon as possible after that. Honda's modules are intended mainly for rooftop applications. The company has been testing the CIGS modules on 16 international sites since 2002 (Hirshman, 2006§). In addition, Showa Shell Sekiyu K.K. was planning to start commercial production at a manufacturing plant producing 20-MW-capacity copper-indium-selenium thin-film in early 2007 in Miyazaki Prefecture (Tsukioka, 2005§).

The results of a 2-year joint research program by Intel Corp. and QinetiQ Ltd. into new transistor technology that substitutes indium antimonide for silicon, which could become a promising candidate for making microprocessors by the middle of the next decade, were made public. The research results obtained from the new transistor research showed a tenfold lower power consumption for the same performance, or conversely a threefold improvement in transistor performance for the same power consumption, compared with traditional transistors made from silicon (Intel Corp., 2005§).

Outlook

Indium consumption is expected to increase during the next few years. Leading the way are indium applications for ITO intended for LCDs and PDPs. In Japan, sales of LCD and plasma screens surpassed cathode-ray tube televisions for the first time, reflecting the increasing market for FPDs (American Metal Market, 2006b). The FPD market was expected to continue growing through 2008, though at slowing rates of increase. Most ITO producers announced capacity increases in 2005 although use of ITO coatings for applications such as architectural glass decreased owing to continued high prices (Compound Semiconductor, 2005§). The market for LCDs was expected to grow 40% in 2006 (Ryan's Notes, 2005a). There is some time before differences between supply and demand make themselves known. It takes 9 to 12 months to turn indium metal into powder, then into an ITO target supplied to an LCD manufacturer (Ryan's Notes, 2005b).

On the supply side, a critical element will be the ability of individual countries to recycle indium-containing electronic components. Because indium is mostly a byproduct of zinc mining and smelting, it will be hard to increase primary production unless there is an increase in zinc production. During the past decades, dwindling zinc prices forced some high cost and low-grade underground zinc mines and a few older and less efficient zinc refineries to close. Now, the price of zinc has risen, and with it zinc production could be expected to rise. With that scenario, primary indium production is expected to also increase. Higher prices for indium have resulted in increased recycling. Despite increasing demand for indium, worldwide supply is expected to be adequate with increased primary production and recycling.

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TABLE 1
U.S. IMPORTS FOR CONSUMPTION OF UNWROUGHT AND WASTE AND SCRAP OF INDIUM, BY COUNTRY[1, 2]

Country	2004 Quantity (kilograms)	2004 Value (thousands)	2005 Quantity (kilograms)	2005 Value (thousands)
Belgium	10,300	$5,860	8,030	$7,170
Canada	22,800	12,100	13,200	10,700
Costa Rica	2	12	1,580	360
Denmark	30	4	--	--
China	66,100	20,200	60,400	29,300
Estonia	--	--	109	19
France	7,150	283	91	45
Germany	339	99	3,220	1,500
Hong Kong	3,230	1,780	2,360	1,660
India	1	3	--	--
Italy	230	126	--	--
Japan	22,300	12,600	31,900	26,700
Korea, Republic of	--	--	12,500	9,270
Macao	100	84	--	--
Mexico	35	3	--	--
Netherlands	546	431	462	406
Peru	2,130	1,330	3,350	3,200
Russia	3,560	2,110	825	878
Singapore	--	--	1,340	1,470
Taiwan	100	49	--	--
United Kingdom	3,510	1,750	2,260	1,750
Total	143,000	58,800	142,000	94,400

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes indium powder.

Source: U.S. Census Bureau.

TABLE 2
INDIUM: ESTIMATED WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005
Belgium	40	40	30	30	30
Canada	45	45	50	50	50
China	190 r	160 r	180 r	200	300
France	65	65	10	10	10
Germany	10	10	10	10	10
Italy	5	5	5	5	5
Japan	55	60	70	70	70
Kazakhstan	NA	NA	NA	NA	NA
Netherlands	5	5	5	5	5
Peru	4 [3]	6 [3]	6	6	6
Russia	15	15	15	15	15
Ukraine	NA	NA	NA	NA	NA
United Kingdom	5	5	5	5	5
Total	439 r	416 r	386 r	406	506

rRevised. NA Not available.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 16, 2006.

[3]Reported figure.

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IODINE

By Phyllis A. Lyday

Domestic survey data and tables were prepared by Lisa D. Miller, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Three producers of crude iodine supplied about 28% of domestic demand in 2005 based on apparent consumption (table 1). Domestic and imported iodine was consumed in intermediate products prior to being sold to consumers (table 2). Iodine and its derivatives were used principally in animal feed, catalysts, colorants, inks, pharmaceutical and medical applications, photographic equipment, sanitation or disinfectants, and rosin stabilizers. Published prices for crude iodine in 2005 are found in table 3. Imports of crude iodine decreased by 10%, and imports of potassium iodide (KI) decreased by 32% (table 4). Exports of crude iodine increased by 109%, and exports of potassium iodide decreased by 34% during 2005 (table 5). Because some exports and imports are in product categories rather than listed as elemental iodine, net imports are not clearly distinguished. The United States is the world's third-ranked iodine producer, following Chile and Japan (table 6).

Commercial crude iodine normally has a minimum purity of 99.5% to 99.8%, depending on the supplier. Impurities, in order of quantity, are chiefly insoluble materials, iron, sulfuric acid, and water. The U.S. Pharmacopeia specifies an iodine content of not less than 99.8%. The Committee on Analytical Reagents of the American Chemical Society allows a maximum of 0.005% total bromine and chlorine and 0.010% nonvolatile matter.

Legislation and Government Programs

The revised fiscal year 2005 Annual Materials Plan authorized the disposal of 453,593 kilograms (kg) (1 million pounds) of crude iodine from the National Defense Stockpile (NDS) classified as excess to goal (U.S. Department of Defense, 2004§[1]). Stocks of iodine classified as excess to goal at the end of fiscal year 2005 (September 30, 2005) under the authority of the Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (Public Law 108-375, enacted October 28, 2004) were all subject to disposal limits. On February 7, 2005, the Defense National Stockpile Center (DNSC) announced the award of 113,000 kg (250,000 pounds) of crude iodine valued at $1.8 million ($15.87 per kilogram or $7.20 per pound) (Defense National Stockpile Center, 2005d). On May 5, 2005, the DNSC announced iodine basic ordering agreement (BOA) sales of 113,000 kg (250,000 pounds) for $2 million ($17.64 per kilogram or $8.00 per pound) (Defense National Stockpile Center, 2005c). On August 5, 2005, the DNSC announced iodine BOA sales for July 2005 of 113,000 kg (250,000 pounds) for $2.2 million ($19.40 per kilogram or $8.80 per pound) (Defense National Stockpile Center, 2005e). On November 9, 2005, the DNSC announced iodine BOA sales for October 2005 of 113,000 kg (250,000 pounds) for $2.3 million ($20.28 per kilogram or $9.20 per pound) (Defense National Stockpile Center, 2005f). On September 7, the DNSC announced changes in shipping instructions, payments, and solicitation notification (Defense National Stockpile Center, 2005a). On November 14, 2005, the revised Annual Materials Plan for fiscal year 2006 was released, allowing 453,000 kg (1 million pounds) to be sold (Defense National Stockpile Center, 2005b).

Iodide is an essential component of thyroid hormones. Perchlorate interferes with iodide uptake into the thyroid gland; perchlorate ingestion disrupts normal thyroid functions. In January, the National Research Council of the National Academies of Sciences published its technical review of the "Health Implication of Perchlorate Ingestion" report. From this review, the U.S. Environmental Protection Agency (EPA) established an official reference dose of 0.0007 milligram per kilogram per day of perchlorate (U.S. Environmental Protection Agency, 2005§).

The Food and Drug Administration (FDA) has approved KI in tablet form as a nonprescription drug for use as a "blocking agent" to prevent the human thyroid gland from absorbing radioactive iodine. On January 12, the FDA granted approval for ThyroShield™ (potassium iodide oral solution, USP) at a concentration of 65 milligrams per milliliter (mg/ml) for children (New York Jewish Times, 2005§).

Iodine, used with anhydrous ammonia and pseudoephedrin to make methamphetamine (meth), was first synthesized by a Japanese chemist in 1919 and used by both Axis and Allied troops in World War II to keep them alert and motivated. In the 1950s it was commonly prescribed as a weight loss aid, to fight depression, and to give housewives a boost. The Federal Government criminalized most uses of the drug in 1970. In 2005, it was still prescribed for the treatment of attention-deficit disorder and narcolepsy. More than 12 million Americans have tried methamphetamine, and 1.5 million are regular users, according to Federal estimates. Meth-making operations had been uncovered in all 50 States. Police nationwide ranked methamphetamine the No. 1 drug they battle. Many retailers have moved nonprescription cold pills behind the pharmacy counter, where meth cooks have a harder time obtaining the ingredients (Jefferson, 2005).

Some companies in the Philippines are selling and/or manufacturing water purification components, such as filters containing iodine and other iodinated resins as a disinfectant. The World Health Organization's 2003 "Background Document for Development of Drinking Water Quality" states that iodine is not recommended for long-term disinfection. Long term iodide exposure at levels exceeding the recommended energy nutrient intake may result in iodism. The symptoms resemble a sinus cold, but may also include salivary gland swelling, gastrointestinal irritation, acne, metallic or brassy taste, conjunctiva irritation, and edema of the eyelids. The recommended energy nutrient intake for iodine of Filippinos according to the Food and Nutrition

[1]References that include a section mark (§) can be found in the Internet References Cited section.

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Research Institute, depending on age and sex, ranges from 80 to 120 micrograms per day for children, 120 to 150 micrograms daily for adults, and 200 micrograms per day for pregnant women (Subong, 2006).

Production

The U.S. Geological Survey derived domestic production data for iodine from a voluntary canvass of U.S. operations. The three companies to which a survey request was sent responded, representing 100% of the total production (tables 1, 6).

In 1987, IOCHEM Corp. (owned by the Kita family and Tomen Corp.) began producing iodine at a plant 1.2 kilometers east of Vici, Dewey County, OK. This was the leading U.S. iodine plant. The majority of production was shipped to Schering AG of Germany under a long-term contract. IOCHEM reported having nine production wells and four injection wells with a total production capacity of 1,400 metric tons per year (t/yr) at Vici. In 2005, a project was approved by the Oklahoma Department of Agriculture, Food, and Forestry to generate electricity from hot brine used to extract iodine. The project was expected to convert up to 10% of the estimated 30 megawatts of excess energy currently sent to cooling ponds. Current brine reaches the surface at 86° C (186° F). Also participating in the Brine Electric Inc. project are Nathaniel Energy, Denver, CO; Northwestern Electric Power Cooperative, Woodward, OK; and High Plains Resource Conservation and Development, Buffalo, NY (Carson, 2005).

North American Brine Resources began operating a miniplant located at Dover, Kingfisher County, OK, in 1983. In 2004, the miniplant continued operating at an oilfield-injection-disposal site near Dover.

Woodward Iodine Corp., Woodward County, OK, was wholly owned by Ise Chemical Corporation of Japan and began production in 1977. It produced iodine from 22 brine wells and injected waste through 10 injection wells. MIC Specialty Chemicals, Inc. (a subsidiary of Mitsubishi International Corp.) was the exclusive distributor for iodine produced by Woodward.

Consumption

Establishing an accurate end-use pattern for iodine is difficult because iodine-containing intermediates are marketed before reaching their ultimate end uses.

Biocides and Disinfectants.—Iodine is an effective germicide for a wide range of microorganisms. Iodine was used with iodophors in disinfectants for use in dairies, food processing plants, hospitals, and laboratories. Polyvinyl pyrrolidinone-iodine (PVP) complexes were used because of bactericidal, fungicidal, germicidal, and general disinfecting properties. Globaline tablets were used by the U.S. military to disinfect water supplies without boiling.

Catalyst.—Iodine is used in the production of acetic acid using the Monsanto process. The process involves methanol carbonylation with an iodide-promoted rhodium complex as the catalyst. Iodide catalysts, such as titanium tetraiodide and aluminum iodide, are used in the production of butane and butene to butadiene and in the preparation of stereoregular polymers.

Chemicals.—Iodine is used as a stabilizer in the manufacture of nylon for tire cord and carpets and for converting rosins, tall oil, and other wood products to a more stable form.

Nutrition.—Iodine is a necessary mineral in mammals for a healthy thyroid. The use of iodized salt has significantly reduced the incidence of goiter in mammals. Iodine deficiency disorder can be prevented by consuming about 150 milligrams of iodine per day for a human adult.

Pharmaceuticals.—Radiopaque agents are drugs used to help diagnose certain medical problems and may contain iodine, which absorbs x rays. Radiopaque-diagnosed medical problems include brain disorders, cardiac disease, central nervous system disorders, cerebrospinal fluid, disk disease, gastrointestinal (gall bladder) disorders, peritoneal disorders, splenic and portal vein disorders, urinary track disorders, and vascular disease. KI was used as an expectorant in cough medicines. Hydriodic acid and potassium iodide were used in the synthesis of amphetamine, ethylamphetamine, and methamphetamine stimulants controlled under 21 CFR §1308.11.

Television Panels.—Liquid crystal display (LCD) flat panel screens are replacing the cathode-ray tubes of older televisions. Merck K GaA of Germany produces 60% of the world's potassium iodide LCD material. Digital radiography screens use cesium iodide in the flat panel detectors.

Weather Modification.—Cloud seeding involves the introduction of additional nuclei (silver iodide) which causes more water drops to condense within the cloud and fall to earth. Cloud-top seeding uses generators on the ground to disperse the particle upward or by dropping flares out of planes directly into the cloud system and is performed between the temperatures of -5° C and -10° C. Cloud seeding is used internationally to increase precipitation in the form of rain or snow.

Other.—Uses included batteries, brachytherapy [a minimally invasive procedure that implants small radioactive iodine pellets (called seeds) about the size of a grain of rice into the prostate where they irradiate the cancer from inside the gland] high-purity metals, inks and colorants, laboratory reagents, lubricants, motor fuels, and photographic chemicals.

Prices

Actual prices for iodine are negotiated on long- and short-term contracts between buyers and sellers. The average declared cost, insurance, and freight (c.i.f.) value for imported crude iodine was $16.74 per kilogram. The average declared c.i.f. value for iodine imported from Chile was $17.14 per kilogram. The average declared c.i.f. value for imported crude iodine from Japan was $15.34 per kilogram. The average sale price of iodine sold by the DNSC was $17.57 per kilogram ($7.97 per pound). Published yearend U.S. prices for iodine and its primary compounds are listed in table 3 and figure 1. Because of the quarterly sales of iodine periodically since 1981, iodine prices have fluctuated.

Solicitations for NDS iodine sales are made on a quarterly basis. Since 1998, ten companies—Champa Purie-Chem Industries (India), Deepwater Chemicals Inc., Dyestuff International, Dewey Chemicals Inc., G. Amphray Lab (India), H&S Chemical Co. Inc., MIC Specialty Chemicals Inc., SQM North America, Venture Tech, and West Agro Chemical Inc.—

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have purchased stockpile iodine. During the past year, the iodine market was undersupplied as increased global demand for iodine in 2005 resulted in price increases.

Foreign Trade

The U.S. Government adopted the harmonized commodity description and coding system as the basis for its export and import tariff and statistical classification systems. The system is intended for multinational use as a basis for classifying commodities in international trade for tariff, statistical, and transportation purposes. It includes unification of resublimed and crude iodine under the same code and free duty rate. Values that differ significantly could be a result of items being placed in the wrong category as a result of mistakes in reporting or to protect military items (tables 4-5). The International Trade Administration of the U.S. Department of Commerce provides monthly and annual import and export data by Harmonized Tariff Schedule of the United States classification.

World Industry Structure

Worldwide production of iodine in 2005 was estimated to be 25,400 metric tons (t), of which 15,600 t (59%) was produced in Chile, and 7,300 t (29%) was produced in Japan. Industrial uses of iodine are still increasing, and areas of applications are expanding beyond the established markets, which are as follows: catalysts, germicides and disinfectants, pharmaceuticals, various additives, x-ray contrast media, and other.

World Review

Chile.—Atacama Minerals Corp. reported that the purchase and sale agreement with ACF Minera S.A. to acquire ACF's 50% interest of the Aguas Blancas Mine located in the Atacama Desert of northern Chile was completed. An agitated-leach demonstration plant was to be built that would double the iodine production capacity to 1,500 metric tons per year (t/yr). The expansion was expected to cost $10 million and take 18 months to complete (Mining Engineering, 2005). AMEC International Chile S.A. (AMEC), an independent engineering consulting firm, prepared a resource and reserve estimate dated May 2005. The estimated reserves for the Aguas Blancas deposit estimated indicated resources of 34.8 million metric tons (Mt) of 483-part-per-million iodine (Shane, 2005).

Sociedad Química y Minera de Chile S.A. (SQM) was the world's leading producer of iodine. All production was from caliche ore. The geologic origin of the caliche ore is not clear, but it is thought to be of sedimentary origin. At the Pampa Blanca Mine located in the Sierra Gorda area the ore is leached in piles to obtain solutions of iodine, which are transported to solar evaporation ponds. In June 2004, SQM announced a 3-yea, $400 million expansion to include a 25% expansion in iodine production. In January 2005, SQM placed a 21-year unsecured bond on the Chilean market to finance the capital expenditure program (Harris, 2005).

SQM produced intermediate iodine at its five processing facilities, Mapocho—Maria Elena, Nueva Victoria, Pampa Blanca, and Pedro de Valdivia. The company planned to increase iodine production in the Nueva Victoria facility.

Japan.—Japan was the world's second-ranked producer of iodine. Iodine was manufactured in Chiba, Miyazaki, and Niigata Prefectures; Chiba Prefecture accounted for about 90% of all production in Japan. The following 8 companies operated 11 plants in Japan: Godo Shigen Sangyo Co., Ltd., Chiba Prefecture, 200 metric tons per month (t/mo); Ise Chemical Co., Ltd., two plants in Chiba Prefecture and one in Miyazaki Prefecture, 300 t/mo; Japan Energy Development Co., Ltd., Niigata Prefecture, 30 t/mo; Kanto Natural Gas Development Co., Ltd., Chiba Prefecture, 100 t/mo; Nihon Tennen Gas Co., Ltd., two plants in Chiba Prefecture, 100 t/mo; Nippoh Chemicals Co., Ltd., Chiba Prefecture, 60 t/mo; Teikoku Oil Co. Ltd., Chiba Prefecture, 50 t/mo; and Toho Earthtech, Inc., Niigata Prefecture, 60 t/mo.

Current Research and Technology

A study published in the Journal of the American Academy of Dermatology suggested that a high-dairy diet could contribute to teenage acne; however, a dermatologist suggested that the cause is the iodine levels in milk rather than the presence of hormones and bioactive molecules in milk. Several studies connected iodine consumption and acne development. The iodine enters the milk through animal feed and sanitizing solutions (Pepling, 2006).

An adhesive containing an iodide compound that secures the glass covering the charge-coupled device in digital cameras manufactured by Sony Corp. of Japan could possibly affect 10 million units. The compound reacted with water to generate a gas that corroded the bond and resulted in broken connections (Asakawa and Ootsuki, 2006).

Silver iodide nanoparticles could improve many aspects of current LCD technology by improving color, lifetime, and efficiency. Nanomaterials can diminish scattering and leveraging novel physical effects that could improve the optical, electronic, and mechanical properties. Nanotechnology has added value to flat panel displays by lowering cost and producing improvements in functionality. Organic light-emitting diode displays represent an application for quantum confinement, allowing quantum-dot color to be tuned to a particle size (Sobolev, 2005§).

Outlook

During the past decade, iodine production capacity in Chile and the United States has doubled, ensuring an adequate world supply. Most of the iodine producers were operating close to full capacity, and there may be some tightness of supply in the short term. Domestic demand was expected to remain at current levels because production of derivatives to supply the external market was expected to move overseas.

Biocides and Disinfectants.—Demand for biocides and disinfecting chemicals remained high. Growth in the water treatment market moved from South America to India and Pakistan and then into China. Expanding treatment of water supplies for municipalities will probably increase the demand for these chemicals in the future.

Catalyst.—Iodine is used as a catalyst in the making of various chemicals, including acetic acid. With the increase in

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feedstock costs for natural gas and resulting increases in prices of chemicals, demand for iodine is likely to decrease.

Nutrition.—Iodine is used in animal feed to prevent goiter and regulate metabolism. People commonly receive iodine from KI added to salt. Demand for potassium iodide as a preventative of cancer of the thyroid in the event of a nuclear accident increased sales of pills to government and private individuals. More countries are providing these pills to individuals, and the demand for this compound is increasing.

Other.—Recent developments in digital imaging have produced electronic prints and overhead transparencies without the need for wet processing film. This would appear to cause a decrease in iodine usage in color film and film developing; however, 75% to 85% of all televised programs seen during prime time are recorded on 35-millimeter motion picture film and then transferred to videotape or laser disc for display. Furthermore, the majority of feature films for movie theater presentations are shot and printed on film because film provides higher image resolution. In the next decade, uses of iodine in films and processing may be limited to specialty film imaging as digital imagery technology for motion pictures improves and digital equipment and printers become more affordable.

Use of x-ray contrast media, which contain as much as 60% iodine, is expected to continue to grow between 4% and 5% per year. More medical tests on an aging population will result in increased demand for iodine-containing x-ray contrast media.

New uses of fluoroiodocarbon as halogen replacements may increase demand for iodine in fire suppression chemicals. More tests need to be completed on the iodated fluorocarbons before they are acceptable, but preliminary tests were promising. Supplementation programs designed to alleviate iodine deficiency disease (IDD) in China and India will continue to consume large amounts of iodine to prevent IDD. In Chile and Mexico, individual water purification units that use iodine are a new application of an existing purification process using iodine in camping, hiking, and military water supplies. Purification applications could become significant consumers of iodine. The use of iodine to treat wood for prevention of damage by insects was approved by the EPA to replace the use of chrome-copper-arsenates (CCAs). The potential for demand in this use is high because the PVP treatment material is not water soluble like other replacement materials for CCA treatments.

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TABLE 1
SALIENT IODINE STATISTICS[1]

(Metric tons and dollars)

	2001	2002	2003	2004	2005
United States:					
Production	1,290	1,420	1,090	1,130	1,570
Imports[2]					
Quantity, for domestic consumption	5,030	6,190	5,750	5,700	6,250
Price, average[3]	13.94	12.70	11.81	13.38	16.75
Exports[2]	1,460	1,580	1,590	1,270	2,660
Consumption:					
Reported[4]	3,560	4,540	3,930	4,070	4,680
Apparent[5]	4,730	6,520	5,240	5,560	5,510
World, production[e]	20,700	21,000	22,900 [r]	24,800 [r]	25,400

[e]Estimated. [r]Revised.

[1]Data are rounded to no more than three significant digits, except prices.

[2]Source: U.S. Census Bureau information reported by Harmonized Tariff Schedule of the United States code 2801.20.0000

[3]Cost, insurance, and freight valuation.

[4]Reported by voluntary response to the U.S. Geological Survey from a survey of domestic establishments.

[5]Calculated using domestic production plus imports minus exports plus adjustments for Government and domestic industry stock changes.

TABLE 2
DOMESTIC CONSUMPTION OF IODINE, BY PRODUCT[1]

	2004		2005	
Product	Number of plants	Quantity (metric tons)	Number of plants	Quantity (metric tons)
Inorganic compounds:				
Crude iodine	NA	NA	8	833
Resublimed iodine	7	527	8	116
Potassium iodide	5	525	4	578
Sodium iodide	4	49	5	375
Hydriodic acid	2	46	2	131
Potassium iodate	3	66	3	33
Miscellaneous iodate, and iodides[2]	2	51	2	25
Other inorganic compounds	4	535	3	312
Total	18 [3]	1,800	22 [3]	2,470
Organic compounds:				
Ethylenediamine dihydroiodide	2	185	3	197
Povidine-iodine (idophors)	3	395	2	397
Other organic compounds[4]	5	1,690	5	1,680
Total	18 [3]	2,270	22 [3]	2,280
Grand total reported consumption[5]	XX	4,070	XX	4,680
Apparent consumption[6]	XX	5,560	XX	5,510

NA Not available. XX Not applicable.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes ammonium iodide, calcium iodate, and cuprous iodide.

[3]Nonadditive because some plants produce more than one product concurrently.

[4]Includes methyl and/or ethyl iodide.

[5]Reported by voluntary response to the U.S. Geological Survey in a survey of domestic establishments.

[6]Calculated using domestic production plus imports minus exports plus adjustments for Government and domestic industry stock changes.

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TABLE 3
YEAREND 2005 PRICES OF ELEMENTAL IODINE AND SELECTED COMPOUNDS

Elemental iodine/compounds	Value[1] Dollars per kilogram	Dollars per pound
Iodine, crude, drums	23.00-25.00	10.43-11.34
Potassium iodide, U.S. Pharmacopeia, drums, 5,000-pound lots, delivered	25.76	12.27

[1]Conditions of final preparation, transportation, quantities, and qualities not stated are subject to negotiations and/or somewhat different price quotations.

Sources: Chemical Market Reporter, 2005, Current prices of chemicals and related materials, v. 267, no. 51, December 19, p. 22; U.S. Census Bureau.

TABLE 4
U.S. IMPORTS OF CRUDE IODINE AND POTASSIUM IODIDE FOR DOMESTIC CONSUMPTION, BY COUNTRY OF ORIGIN[1]

Type and country of origin[2]	2004 Quantity (metric tons)	2004 Value[3] (thousands)	2005 Quantity (metric tons)	2005 Value[3] (thousands)
Iodine, crude:				
Belgium	--	--	18	304
Canada	(4)	34	--	--
Chile	3,920	51,800	4,850	83,100
France	22	291	30	481
Germany	5	65	--	--
India	--	--	(4)	13
Japan	1,570	20,600	1,350	20,700
Mexico	71	1,000	--	--
Netherlands	--	--	(4)	2
Russia	21	282	7	102
Spain	89	1,210	--	--
United Kingdom	(4)	3	--	--
Total	5,700	75,300	6,250	105,000
Potassium iodide:[5]				
Brazil	161 r	2,690	74	1,570
Canada	287 r	4,810	233	5,170
Chile	200 r	3,570	136	2,990
Japan	5 r	19	3	21
Other[6]	25 r	440 r	11	225
Total	678	11,500	458	9,970

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Import information for crude iodine and potassium iodide are reported by Harmonized Tariff Schedule of the United States codes 2801.20.0000 and 2827.60.2000, respectively.

[3]Declared cost, insurance, and freight valuation.

[4]Less than ½ unit.

[5]Gross potassium iodide contains 76% crude iodine.

[6]Includes China (2004), Germany, and India (2004).

Source: U.S. Census Bureau.

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TABLE 5

U.S. EXPORTS OF CRUDE IODINE AND POTASSIUM IODIDE, BY COUNTRY OF ORIGIN[1]

Type and country of origin[2]	2004 Quantity (metric tons)	2004 Value[3] (thousands)	2005 Quantity (metric tons)	2005 Value[3] (thousands)
Iodine, crude/resublimed:				
Australia	--	--	20	61
Brazil	(4)	7	2	20
Canada	347	6,250	385	7,430
Dominican Republic	--	--	6	97
Germany	258	2,770	600	8,840
Jamaica	(4)	3	1	20
Japan	347	1,210	121	1,930
Korea, Republic of	(4)	14	34	168
India	18	166	371	2,970
Malaysia	6	24	6	30
Mexico	143	858	122	547
Saudi Arabia	--	--	2	3
Venezuela	12	182	29	218
United Kingdom	2	36	1	21
Other[5]	139	290 r	956	5,540
Total	1,270	11,800	2,660	27,900
Potassium iodide:[6]				
Australia	3	70	(4)	20
Colombia	(4)	11	(4)	9
France	29	591	4	134
Japan	1 r	22 r	3	41
Korea, Republic of	(4)	10 r	5	113
Mexico	5	125	6	177
Netherlands	2	56	1	38
Singapore	(4)	11	(4)	3
Taiwan	55	912 r	24	493
United Kingdom	5	120	(4)	8
Other[7]	1	50	22	515
Total	102	1,980	67	1,550

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Export information for iodine, crude/resublimed and potassium iodide are reported by Harmonized Tariff Schedule of the United States coders 2801.20.0000 and 2827.60.2000, respectively.

[3]Declared free alongside ship valuation.

[4]Less than ½ unit.

[5]Includes Argentina (2005), Belgium (2005), Chile (2005), Colombia (2005), Costa Rica (2004), El Salvador (2004), France, Hong Kong (2004), Italy (2004), the Netherlands (2005), New Zealand (2005), Pakistan (2005), Peru (2004), Singapore, Sri Lanka (2005), Taiwan (2004), Turkey (2005), and the United Arab Emirates (2005).

[6]Potassium iodide contains 76% crude iodine.

[7]Includes Belgium, China (2005), Germany (2005), Israel, Indonesia, Jamaica (2005), Malaysia, Peru, the Philippines (2005), Sierra Leone (2004), Switzerland (2005), Turkey (2005), and Venezuela.

Source: U.S. Census Bureau.

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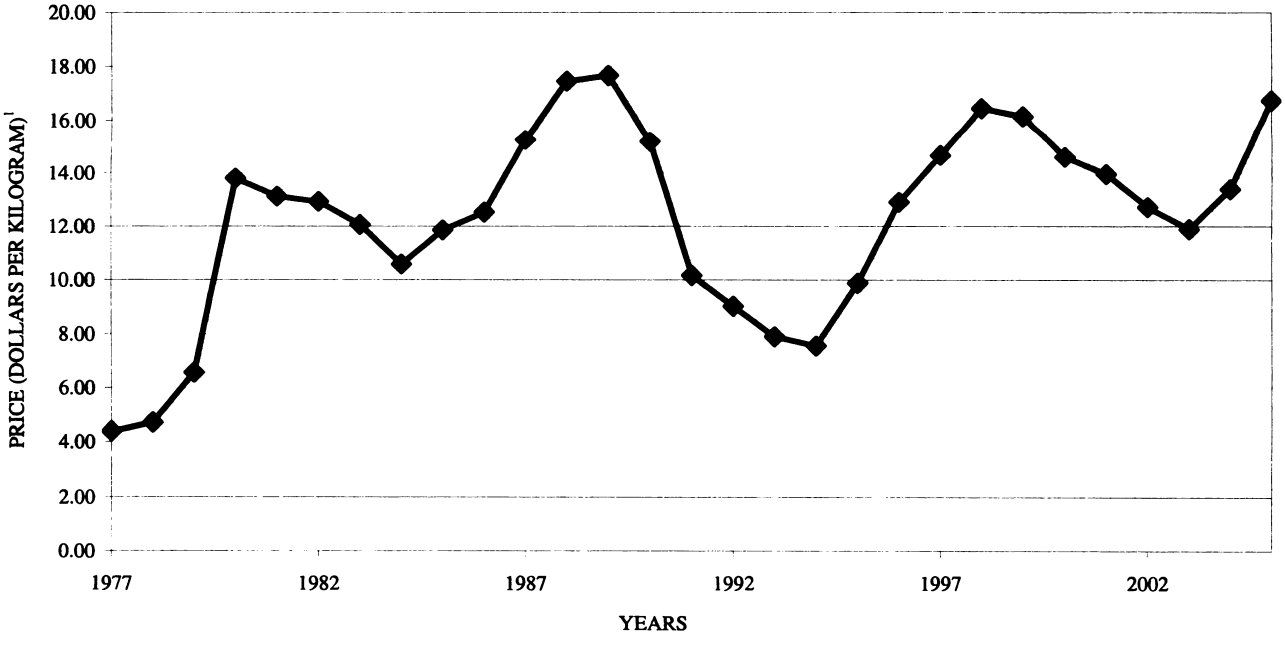
TABLE 6
CRUDE IODINE: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005
Azerbaijan	300	300	300	300	300
Chile[3]	11,355 [4]	11,648 [4]	13,916 [r, 4]	14,931 [r, 4]	15,000
China	500	500	500	550	550
Indonesia	75	75	75	75	75
Japan	6,643 [4]	6,548 [4]	6,524 [4]	7,264 [r, 4]	7,300
Russia	300	300	300	300	300
Turkmenistan	200	200	200	250	270
United States[4]	1,290	1,420	1,090	1,130	1,574
Uzbekistan	2	2	2	2	2
Total	20,700	21,000	22,900 [r]	24,800 [r]	25,400

[r]Revised.
[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]Table includes data available through June 10, 2006.
[3]Includes iodine production reported by Servicio Nacional de Geologia y Minería.
[4]Reported figure.

FIGURE 1
HISTORIC IODINE PRICES



[1]Cost, insurance, and freight valuation.

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IRON AND STEEL

By Michael D. Fenton

Domestic survey data and tables were prepared by Steven H. Diamond, statistical assistant, and world production tables were prepared by Linder Roberts (pig iron) and Glenn J. Wallace (steel), international data coordinators.

The gradual recovery in the global economy, beginning in late 2003, continued through 2004, but showed signs of declining slightly in 2005, according to the World Bank (World Bank, The, 2005§[1]). The World Bank reported that the world's economy had an estimated gross domestic product (GDP) increase of 3.8% for 2004, and forecast a reduction to be about 3.2% for 2005. The United States continued to be the world's leading economy, having an estimated GDP of about $12.0 trillion in 2005 (U.S. Office of Management and Budget, 2005§). The U.S. GDP increased during 2005, according to the World Bank, the Bureau of Economic Analysis, and the Organisation for Economic Co-operation and Development (OECD), at a rate of 3.6%, 3.5%, and 3.2%, respectively (Newratings, 2005§; World Bank, The, 2005§; Bureau of Economic Analysis, 2006§). The International Monetary Fund (IMF) forecast the U.S. GDP growth of 3.5% for 2005 (Newratings, 2005§).

U.S. apparent steel consumption, an indicator of economic growth, decreased to 109 million metric tons (Mt) in 2005 from 117 Mt in 2004.

Mittal Steel Co., the largest steel company in the world, valued at $17.8 billion with a capacity of 58 million metric tons per year (Mt/yr) and projected annual revenue of $32 billion, made a surprise $23 billion bid for its closest rival, Arcelor SA of Luxembourg, on January 27, 2006. If this takeover succeeds, Mittal would control an estimated 11% of the world's annual crude-steel output and produce more than 91 Mt/yr. Mittal's North American steelmaking capacity comprises 21 mills, 17 of which are in the United States. Mittal would be in a strong position to influence steel and raw material prices. Mittal is seen by many industry experts as signifying the future of the world steel industry, which would consist of international consolidations that result in several very large, high-capacity companies offering a wide range of products, having global buying power, and raw materials security.

Company consolidation activity was high during 2005, as companies sought to reinvest their gains from the prior year's steel sales. Major deals included: Mittal Steel Co.'s acquisition of International Steel Group; Nucor Corp.'s purchase of Fort Howard Steel Co. and Marion Steel Co.; Steel Dynamics, Inc.'s plan to purchase Roanoke Electric Steel Corp.; the purchase of Republic Engineered Products Inc. by Mexico's Grupo Simec SA de CV; the purchase of Copperweld Holding Co. by Dofasco Inc.; and ThyssenKrupp AG's friendly takeover offer for Dofasco. The steel industry generates 1.2 million jobs and contributes $350 billion to the U.S. economy (American Iron and Steel Institute, 2006§). Steel productivity has more than tripled during the past 25 years.

The American Iron and Steel Institute (AISI) reported U.S. production of iron and steel and shipments of steel mill products. These data can be regarded as representing 100% of the raw steel producers in the United States. World production of iron and steel is reported by the International Iron and Steel Institute and by foreign government agencies. Consistent with international usage and Federal Government policy, the U.S. Geological Survey reported all data on iron and steel in metric units unless otherwise noted.

Environment

The U.S. Environmental Protection Agency proposed in 2003 amendments to national emissions standards for hazardous air pollutants (NESHAP) for integrated iron and steel manufacturing (American Metal Market, 2005). The NESHAP established limitations for emissions sources in each new sinter plant, blast furnace, and basic oxygen processing shop. Later, the final standards were overturned as a result of a challenge in a lawsuit by five U.S. integrated steel producers and the AISI.

During the past decade, U.S. steelmakers have reduced the energy required to produce one ton of steel by 28%, and plant emissions have been reduced below greenhouse gas emission limits set by the Kyoto Protocol, an agreement made under the United Nations Framework Convention on Climate Change (American Iron and Steel Institute, 2006§).

Production

Raw steel production in the United States decreased during 2005 by 6.4% (American Iron and Steel Institute, 2005, p. 76). Production of raw steel in the United States decreased to 94.9 Mt in 2005 from 99.7 Mt in 2004 (table 1). The AISI estimated raw steel production capability to be 108 Mt, up from 105 Mt in 2004. Production represented 87.5% of estimated capacity compared with 94.6% in 2004.

Integrated steel producers smelted iron ores to liquid iron in blast furnaces and used basic oxygen furnaces to refine this iron with some scrap to produce raw liquid steel. The basic oxygen process was used to make 42.7 Mt of steel in the United States (American Iron and Steel Institute, 2005, p. 72). The use of this process declined to 45.0% of total steel production in 2005 from 47.9% in 2004. The integrated steel industry in the United States consisted of 8 companies operating ironmaking and steelmaking facilities at 18 locations (Association for Iron & Steel Technology, 2005). Two companies operated combined oxygen and electric arc furnace (EAF) facilities.

Minimills and specialty mills are nonintegrated steel producers that use EAF to melt low-cost raw materials (usually scrap). They also employ continuous casting machines and

[1]References that include a section mark (§) are found in the Internet References Cited section.

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hot-rolling mills that are often closely coupled to the casting operation. Specialty mills include producers of stainless, alloy-electrical, and tool steel; high-temperature alloys; forged ingots; and other low-volume steel products. In the United States, 51 companies operated 88 EAF plant facilities. These U.S. mills used the EAF steelmaking process to produce 52.1 Mt of steel, about the same as in 2004, and accounted for 55.0% of total steelmaking (American Iron and Steel Institute, 2005, p. 72).

In Canada, three integrated steel companies operated four oxygen steelmaking facilities and one combined oxygen and EAF facility, while seven companies operated nine EAF facilities. In Mexico, two integrated steel companies operated two oxygen steelmaking facilities and 6 companies operated eight EAF facilities.

Raw liquid steel is mostly cast into semifinished products in continuous casting machines. Only 3.2% of U.S. production was cast in ingot form and subsequently rolled into semifinished forms; this represented about the same as that of 2004. Continuous casting production was 91.8 Mt, or 96.8% of total steel production, compared with 96.8 Mt, or 96.1%, in 2004 (American Iron and Steel Institute, 2005, p. 73).

Consumption

Steel mill products are produced at a steel mill either by forging or rolling into forms normally delivered for fabrication or use. Some companies purchase semifinished steel mill products from other steel companies and use them to produce finished steel products. To avoid double counting steel mill product shipments under these circumstances, steel mills identify any shipments of steel mill products to other companies that are reporters of steel mill product shipments. The accumulated shipments of all companies less the shipments to other reporting companies are identified as net shipments.

The U.S. apparent consumption of steel mill products was 109 Mt, a 7% decrease from that in 2004. Shipments of steel mill products by U.S. companies decreased by 6% to 95.2 Mt compared with those of 2004 (American Iron and Steel Institute, 2005, p. 25). Export shipments by AISI reporting companies increased to 8.5 Mt from 7.2 Mt in 2004 (American Iron and Steel Institute, 2005, p. 38). Shipments to domestic customers decreased by 5.8% during 2005 (American Iron and Steel Institute, 2005, p. 29). Shipments of construction and contractors' products, the leading single end-use market, was about the same as in 2004. Automotive product shipments increased by 4.5% in 2005. Lumbering, mining, oil and gas, and quarrying industries shipments increased by nearly 20%. Shipments of industrial and agricultural machinery, equipment, and tools decreased by 8%. Appliance shipments; containers, packaging, and shipping material shipments; and steel service center shipments increased by 17%.

Prices

The U.S. Department of Labor, Bureau of Labor Statistics, producer price index for steel mill products was up by 18% to 159.7 for 2005 from 147.2 in 2004 (1982 base=100) (table 1) (U.S. Department of Labor, Bureau of Labor Statistics, 2006§).

Foreign Trade

Exports of steel mill products increased to 8.5 Mt from 7.2 Mt in 2004 (American Iron and Steel Institute, 2005, p. 40). Canada received the largest amount of U.S. exported steel, 5.3 Mt, 14% more than in 2004. Mexico was again in second place, receiving 1.7 Mt, up from 1.5 Mt in 2004 (table 4). Imports of steel mill products decreased by 11% to 29 Mt from 33 Mt in 2004. Brazil, Canada, China, the European Union (EU), Germany, Japan, the Republic of Korea, Mexico, Russia, and Turkey were major sources of steel mill product imports.

The U.S. International Trade Commission voted to keep steel tariffs on some foreign imports for 5 years to avoid harm to the U.S. steel industry, which has been recovering from several bankruptcies since the late 1990s (Wall Street Journal, 2005). The U.S. Department of Commerce had determined that lifting tariffs, established in 1999, would result in more dumped imports of hot-rolled steel from Brazil, Japan, and Russia. The steel industry, which earned its first profit in 2004 after many years, said the tariffs would allow them to maintain financial viability, implement technological improvements, and fund retiree benefits.

On November 18, the U.S. House of Representatives voted to repeal the 5-year-old Continued Dumping & Subsidy Offset Act (CDSOA), also known as the Byrd Amendment, which granted to companies the financial penalties gained from trade dumping cases. Earlier, the World Trade Organization (WTO) ruled several times against the legality of this Act and allowed certain tariffs of as much as $134 million to be assessed against the United States because of its refusal to repeal or modify the CDSOA. Also, the U.S. Government Accountability Office found that about one-half of the $1 billion in penalties collected went to five companies, with about two-thirds of that amount going to three industries, of which steel was one. In December, the Senate agreed on a motion to instruct the conferees to insist that the conference report on the Deficit Reduction Omnibus Reconciliation Act of 2005 (S. 1932) exclude any provision to repeal the CDSOA (Levine, 2005§).

On December 8, the AISI, Canadian Steel Producers Association, Mexican Steel Producers Association, Specialty Steel Industry of North America, and Steel Manufacturers Association made a joint statement about how China's economic strategy constituted the greatest economic and security challenge facing North America (American Iron and Steel Institute, 2005§). These associations, located in North American Free Trade Agreement countries, agree, in part, on the following allegations: (1) Existing trade laws remain underutilized, are inadequately enforced and will probably be strengthened in the context of addressing unfair and disruptive imports of manufactured goods from China; (2) China continues to derive major artificial competitive advantages from its highly undervalued currency, extensive government subsidies, failure to protect intellectual property rights, denial of fundamental worker rights, and lack of environmental controls; (3) China's currency, subsidies, and other unfair trade practices are causing significant harm to competitive U.S. and North American manufacturers; (4) China remains a nonmarket economy, and continues to violate many of its WTO commitments; (5) China's

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economic strategy focuses on the strategic accumulation of productive capacity, export-led growth, and long-term access to raw materials and energy resources; and (6) China's economic strategy has important national security implications for the United States and North America as a whole.

Imports of semifinished steel by steel companies must be taken into consideration in evaluating apparent consumption (supply) of steel mill products in the United States and the share of the market represented by imported steel (table 6). To avoid double counting the imported semifinished steel and the products produced from it, the amount of semifinished steel consumed by companies that also produced raw steel must be subtracted from domestic consumption. Between 1993 and 2005, semifinished steel imports were in a range between 2.5 and 8.0 Mt/yr. Prior to 1993, the amount was less than 0.2 Mt/yr. Taking the imported semifinished steel into consideration, the share of the U.S. steel market represented by imported steel was an estimated 27% in 2005 compared with 28% in 2004.

Regarding the reporting of imports and exports, "fabricated steel products" are produced from steel mill products but do not include products that incorporate steel products with other materials. Examples of fabricated steel products are fabricated structural steel and steel fasteners. "Other iron and steel products" refers to products that are not produced from steel mill products. Examples of other iron and steel products include iron or steel castings and direct reduced iron (DRI).

World Review

World production of pig iron totaled about 789 Mt, 11% more than that of 2004 (table 10). The pig iron production of the EU was about 107 Mt, slightly less than that of 2004. Germany was the top producer in the EU, producing about 29 Mt, slightly less than that of 2004. China continued to be the leading producer of pig iron in the world, producing more than 330 Mt, 31% more than that of 2004. Japan, Russia, and the United States followed with 83 Mt, 48 Mt, and 37 Mt, respectively. The Republic of Korea's production decreased slightly. Russia and Ukraine were the only major pig iron producers in the Commonwealth of Independent States (CIS). In North America, the only major producer of pig iron was the United States, where production in 2005 decreased 12% from that of 2004. In South America, the only major pig iron producer was Brazil, producing more than 32 Mt. India's production increased slightly above that of 2004.

World capacity for DRI production was estimated to be nearly 53 Mt/yr (Midrex Direct Reduction Corp., 2006). DRI production worldwide was about 55.9 Mt, a 2.3% increase from 54.6 Mt (revised) of 2004. The leading producer of DRI was Venezuela, followed by, in descending order of tonnage, Iran, Mexico, and India (table 10). World DRI production increase in 2005 resulted entirely from new small-capacity rotary kilns started in India. All gas-base DRI capacity in the United States and Canada closed in 2005, as did one plant in Mexico, owing to the significant increase in the price of natural gas in North America. The wholesale price of gas in the United States increased by about 8 times that in the mid-1990s—more than $15 per million British thermal units. DRI production in Australia ended, owing to the closure of a Finmet plant. In 2005, additional DRI capacity of 13 Mt was under construction in India, Malaysia, Qatar, Oman, Russia, Saudi Arabia, Trinidad and Tobago, and the United Arab Emirates. The leading technology was the Midrex process, followed by the HYL I and the HYL III processes.

World production of raw steel was 1.13 billion metric tons (Gt), up from 1.06 Gt (revised) produced during 2004 (table 11). As in previous years, production varied widely among major regions of the world. Asian countries produced about 51% of the world's steel; the EU, 17%; North America, 11%; and the CIS, 10%. During 2005, China was again the world's leading steel producer, exceeding 349 Mt, a gain of 28% compared with that of 2004. In descending order, the leading producers behind China were Japan, the United States, Russia, the Republic of Korea, and Germany. These six countries accounted for 63% of world production. The combined steel production of the six steel-producing countries in the CIS was more than 113 Mt, about the same as that in 2004. Russia and Ukraine remained the top producers in the CIS (table 11).

Outlook

GDP growth may be considered a predictor of the health of the steelmaking and steel manufacturing industries, worldwide and domestically. In 2005, the World Bank forecast that the world's economy would decline slightly after 2004, from an estimated GDP increase of 3.8% in 2004, 3.2% in 2005, 3.2% in 2006, and 3.5% in 2007 (World Bank, The, 2005§). Global economic increase was expected to slow in 2006 by the Institute for International Economics, but with slightly higher GDP increase—4.0% in 2005 and 3.5% in 2006 (Institute for International Economics, 2005§).

The U.S. Office of Management and Budget estimated that the U.S. GDP would be $14,701 trillion in 2009, up 22% from that of 2005 (U.S. Office of Management and Budget, 2005§). The U.S. Congressional Budget Office (2006§) forecast an increase of U.S. GDP by about 3.6% in 2006, 3.4% in 2007, 3.1% on average from 2008 through 2011, and 2.6% on average from 2012 through 2016. The Bureau of Economic Analysis reported GDP growth in the United States for the first 2 quarters of 2006 as 5.6% and 2.5%, respectively (Bureau of Economic Analysis, 2006§). The OECD expected the U.S. GDP to increase by 3.5% in 2006, but only 3.3% in 2007 (Newratings, 2005§). The International Monetary Fund (IMF) and the United Nations Economic Commission for Europe forecast U.S. GDP growth of 3.3% for 2006, whereas, the World Bank forecast 3.5% for 2006 and 3.6% for 2007 (Newratings, 2005§; World Bank, The, 2005§; United Nations, 2006§). The Institute for International Economics (2005§) forecast only 2.0% U.S. GDP increase in 2006.

Forecasts for increase in GDP in the EU made by the European Confederation of Iron and Steel Industries (Eurofer) and the European Central Bank were 1.3% and 1.4%, respectively, for 2005 and 1.8% and 1.9%, respectively, for 2006 (Metal Center News Online, 2006§; Newratings, 2005§). The OECD forecast Japanese GDP growth for 2006 and 2007 was 2.0%, whereas the World Bank forecast 1.8% and 1.7% for these years, and the IMF forecast 2.0% for 2006 (Newratings,

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2005§; World Bank, The, 2005§). The Institute for International Economics (2005§) forecast only 1.5% GDP increase for Japan in 2006. For East Asia and the Pacific, the World Bank forecast for 2006 and 2007 GDP growth of 7.6% and 7.4%, respectively. For South America and the Caribbean, the World Bank forecast for 2006 and 2007 GDP growth of 3.9% and 3.6%, respectively, and the Institute for International Economics (2005§) forecast 3.3% GDP growth for 2006 in South America.

The OECD and the IISI forecast China's 2005 GDP growth as 7.8% (OECD) and 8.0% (IISI), after peaking at 9.1% in 2004. Eurofer and ThyssenKrupp AG forecast the GDP growth for China in 2006 as 8.0% and 8.5%, respectively (ThyssenKrupp, 2005§; Metal Center News Online, 2006§). The Institute for International Economics (2005§) forecast only 7.5% GDP growth for China in 2006, down from 9.5% in 2004.

There appears to be a consensus that GDPs worldwide will decline somewhat after 2005, suggesting that steel manufacturing will decline, as well as the demand for steelmaking raw materials. Nevertheless, the OECD forecasts that global raw steelmaking capacity will increase to more than 1.31 billion metric tons per year (Gt/yr) in 2006 from 1.18 Gt/yr in 2004 (Organisation for Economic Cooperation and Development, 2005§). China accounts for most of this increase—360 Mt in 2006 from 330 Mt in 2005 (China Metal Market, 2006).

Global steel production may reach 1.18 Gt in 2007 (MEPS Steel News, 2006§). Economic activity in China continued to be an important influence on the world economy and steel markets, while being the world's leading steel producer. China's steel production was 350 Mt in 2005, up from 280 Mt in 2004, and would be an estimated 385 Mt in 2006 (China Metal Market, 2006).

Global consumption of finished steel products was estimated to increase about 5.8% to 1,150 Mt in 2007 from 1,087 Mt in 2006—7.3% more than that in 2006. Demand in the United States is expected to increase in 2006 and 2007 by 5.0% and 6.7%, respectively; in the EU to increase by 3.9% and 1.5%, respectively; in Russia and Ukraine to increase by 3.2% and 1.6%, respectively; and in India to increase about 8% during 2006 and 2007. China's steel-product consumption is expected to be 356 Mt, 32% of world demand in 2006 (International Iron and Steel Institute, 2006§).

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TABLE 1
SALIENT IRON AND STEEL STATISTICS[1]

(Thousand metric tons unless otherwise specified)

	2001	2002	2003	2004	2005
United States:					
Pig iron:					
Production[2]	42,100	40,200	40,600	42,300	37,200
Exports[3]	44	34	86	48	51
Imports for consumption[3]	4,370	4,620	3,890	6,400	6,030
Direct-reduced iron:					
Production[4]	120	470	210	180	220
Exports[3]	1	1	5	13	--
Imports for consumption[3]	1,650	2,010	1,940	2,450	2,170
Raw steel production:[5]					
Carbon steel	82,400	83,700	86,100	90,700	85,900
Stainless steel	1,820	2,180	2,220	2,400	2,240
All other alloy steel	5,920	5,680	5,350	6,560	6,710
Total	90,100	91,600	93,700	99,700	94,900
Capability utilization, percent	79.2	88.8	84.9	94.6	87.5
Steel mill products:					
Net shipments[2]	89,700	90,700	96,100	101,000	95,200
Exports[3]	5,570	5,450	7,460	7,200	8,460
Imports[3]	27,300	29,600	21,000	32,900 r	29,200
Producer price index (1982=100.0)[6]	101.3	104.8	109.5	147.2	173.6
World production:[7]					
Pig iron	585,000	610,000	664,000	712,000	761,000
Direct-reduced iron[4]	39,300	43,400	45,200	47,900 r	49,200
Raw steel	853,000	906,000	972,000	1,060,000 r	1,130,000

r Revised. -- Zero.

[1] Data are rounded to no more than three significant digits, except producers price index; may not add to totals shown.

[2] Data are from the American Iron and Steel Institute (AISI).

[3] Data are from the U.S. Census Bureau.

[4] Data are from Midrex Direct Reduction Corp., government, and companies.

[5] Raw steel is defined by AISI as steel in the first solid state after melting, suitable for rolling.

[6] Data are from the U.S. Department of Labor, Bureau of Labor Statistics.

[7] Data are from the U.S. Geological Survey and the International Iron and Steel Institute.

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TABLE 2

MATERIALS CONSUMED IN BLAST FURNACES AND PIG IRON PRODUCED[1]

(Thousand metric tons)

Material	2004	2005
Iron oxides:[2]		
Ores	26	34
Pellets	54,900	50,100
Sinter[3]	7,900	8,200
Total	62,900	58,300
Scrap[4]	1,090	1,250
Coke[2]	15,100	13,800
Pig iron, produced	42,300	37,200

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]American Iron and Steel Institute.

[3]Includes sintered ore and pellet fines, dust, mill scale, and other revert iron-bearing materials; also some nodules.

[4]Mainly briquetted turnings and borings, shredded scrap, etc.; scrap produced at blast furnaces and remelt not included.

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TABLE 3

DISTRIBUTION OF SHIPMENTS OF STEEL MILL PRODUCTS, BY STEEL TYPE, PRODUCT, AND MARKET[1]

	Quantity (thousand metric tons)		Percentage	
	2004	2005	2004	2005
Shipments by steel type:				
Carbon steel	94,700	88,800	93.76	93.25
Alloy steel	4,420	4,700	4.38	4.94
Stainless steel	1,880	1,730	1.86	1.81
Total	101,000	95,200	100.00	100.00
Steel mill products:				
Ingots, blooms, billets and slabs	976	1,160	0.97	1.22
Wire rods	2,350	1,760	2.32	1.84
Structural shapes, heavy	6,640	6,730	6.57	7.07
Steel piling	452	582	0.45	0.61
Plates, cut lengths	5,260	5,830	5.21	6.12
Plates, in coils	4,540	3,470	4.50	3.64
Rails	605	633	0.60	0.66
Railroad accessories	193	196	0.19	0.21
Bars, hot-rolled	6,560	6,300	6.49	6.61
Bars, light-shaped	1,390	1,470	1.37	1.54
Bars, reinforcing	7,340	6,350	7.27	6.67
Bars, cold finished	1,370	1,470	1.36	1.55
Tool steel	22	20	0.02	0.02
Pipe and tubing, standard pipe	1,070	1,030	1.06	1.08
Pipe and tubing, oil country goods	1,850	2,030	1.83	2.14
Pipe and tubing, line pipe	679	366	0.67	0.38
Pipe and tubing, mechanical tubing	1,010	998	1.00	1.05
Pipe and tubing, pressure tubing	39	38	0.04	0.04
Pipe and tubing, stainless	13	14	0.01	0.01
Pipe and tubing, structural	141	130	0.14	0.14
Pipe for piling	30	11	0.03	0.01
Wire	514	607	0.51	0.64
Tin mill products, blackplate	196	163	0.19	0.17
Tin mill products, tinplate	2,070	1,860	2.05	1.95
Tin mill products, tin-free steel	567	493	0.56	0.52
Tin mill products, tin coated sheets	114	96	0.11	0.10
Sheets, hot-rolled	20,600	20,300	20.39	21.30
Sheets, cold-rolled	13,400	11,600	13.25	12.19
Sheets and strip, hot dip galvanized	14,800	13,600	14.64	14.29
Sheets and strip, electrogalvanized	2,310	2,240	2.28	2.35
Sheets and strip, other metallic coated	2,020	1,710	1.99	1.80
Sheets and strip, electrical	403	424	0.40	0.45
Strip, hot rolled	50	36	0.05	0.04
Strip, cold rolled	1,480	1,520	1.47	1.59
Total	101,000	95,200	100.00	100.00
Shipments by markets:				
Service centers and distributors	30,700	27,700	30.36	29.11
Construction	19,900	21,700	19.69	22.83
Automotive	15,000	13,100	14.88	13.79
Machinery	1,300	1,500	1.29	1.57
Containers	2,700	2,740	2.67	2.88
All others	31,400	28,400	31.12	29.81
Total	101,000	95,200	100.00	100.00

[1]Data are rounded to no more than three significant digits, except percentages; may not add to totals shown.

Source: American Iron and Steel Institute.

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TABLE 4

U.S. IMPORTS AND EXPORTS OF STEEL MILL PRODUCTS, BY COUNTRY[1]

(Thousand metric tons)

Country	2004		2005	
	Imports	Exports	Imports	Exports
Argentina	343	4	258	4
Australia	586 r	7 r	533	14
Brazil	3,070	22	2,340	24
Canada	4,960	4,680	5,350	5,310
China	1,680	118	2,150	157
European Union	5,020	230	5,270	421
Germany	1,380	35	1,360	105
Japan	1,280	10	1,250	24
Korea, Republic of	1,490	25	1,640	29
Mexico	3,880	1,540	3,730	1,730
Russia	2,180	--	1,430	--
South Africa	365 r	4	297	7
Sweden	212	2	286	2
Taiwan	801	37	551	24
Turkey	1,990	--	1,220	--
Ukraine	436	--	587	--
Venezuela	384 r	35	441	55
Other	2,770 r	454	493	551
Total	32,800 r	7,200	29,200	8,460

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: American Iron and Steel Institute.

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TABLE 5
U.S. EXPORTS OF IRON AND STEEL PRODUCTS[1]

(Thousand metric tons)

	2004	2005
Steel mill products:		
Ingots, blooms, billets, slabs	258	304
Wire rods	91	146
Structural shapes, heavy	601	666
Steel piling	13	39
Plates, cut lengths	826	1,050
Plates, in coils	533	673
Rails, standard	59	71
Rails, other	23	15
Railroad accessories	26	28
Bars, hot-rolled	410	333
Bars, light-shaped	112	90
Bars, concrete reinforcing	224	253
Bars, cold-finished	131	127
Tool steel	19	19
Pipe and tubing, standard pipe	83	82
Pipe and tubing, oil country goods	285	327
Pipe and tubing, line pipe	150	189
Pipe and tubing, mechanical tubing	8	28
Pipe and tubing, stainless	33	50
Pipe and tubing, nonclassified	298	269
Pipe and tubing, structural	122	161
Pipe for piling	3	4
Wire	144	141
Tin mill products, blackplate	5	7
Tin mill products, tinplate	261	250
Tin mill products, tin-free steel	30	29
Sheets, hot-rolled	582	906
Sheets, cold-rolled	530	565
Sheets and strip, hot-dip galvanized	492	637
Sheets and strip, electrogalvanized	136	232
Sheets and strip, other metallic coated	136	163
Sheets and strip, electrical	122	131
Strip, hot-rolled	183	212
Strip, cold-rolled	266	264
Total	7,200	8,460
Fabricated steel products:		
Structural shapes, fabricated	233	257
Rails, used	28	34
Railroad products	58	94
Wire rope	12	12
Wire, stranded products	21	29
Wire, other products	23	26
Springs	99	112
Nails and staples	27	29
Fasteners	779	931
Chains and parts	26	26
Grinding balls	11	11
Pipe and tube fittings	34	35
Other[2]	119 r	112
Total	1,470 r	1,710
Grand total	8,670 r	10,200

See footnotes at end of table.

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TABLE 5—Continued
U.S. EXPORTS OF IRON AND STEEL PRODUCTS[1]

(Thousand metric tons)

	2004	2005
Cast iron and steel products:		
Cast steel pipe fittings	34	35
Cast iron pipe and fittings	76	23
Cast steel rolls	17	20
Cast grinding balls	25	18
Granules, shot and grit	27	30
Other castings	55	67
Total	234	193

[r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes shapes cold formed, sashes and frames, fence and sign post, architectural and ornamental work, and conduit.

Source: American Iron and Steel Institute.

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TABLE 6

U.S. IMPORTS OF MAJOR IRON AND STEEL PRODUCTS[1]

(Thousand metric tons)

	2004	2005
Steel mill products:		
Ingots, blooms, billets, and slabs	6,730	6,270
Wire rods	3,420	2,270
Structural shapes-heavy	564	575
Steel piling	107	94
Plates, cut lengths	814	997
Plates, in coils	1,060	941
Rails and railroad accessories	222	215
Bars, hot-rolled	1,580	1,500
Bars, light-shaped	226	225
Bars, reinforcing	1,740	1,290
Bars, cold-finished	307	414
Tool steel	163	192
Pipe and tubing, standard pipe	1,170	1,190
Pipe and tubing, oil country goods	1,010	1,510
Pipe and tubing, line pipe	992	1,080
Pipe and tubing, mechanical tubing	558	653
Pipe and tubing, pressure tubing	97	168
Pipe and tubing, stainless	108	122
Pipe and tubing, nonclassified	15	15
Pipe and tubing, structural	495	512
Pipe for piling	9	22
Wire	857	776
Tin mill products-blackplate	58	36
Tin mill products-tinplate	328	391
Tin mill products-tin-free steel	100	92
Sheets, hot-rolled	3,850	2,870
Sheets, cold-rolled	2,350	1,740
Sheets and strip, hot-dip galvanized	2,690	2,100
Sheets and strip, electrogalvanized	105	147
Sheets and strip, other metallic coated	425	431
Sheets and strip, electrical	79	75
Strip, hot-rolled	98	96
Strip, cold-rolled	160	170
Total	32,500	29,200
Fabricated steel products:		
Structural shapes, fabricated	614	808
Rails, used	131	164
Railroad products	126	178
Wire rope	124	127
Wire-stranded products	261	256
Springs	505	529
Nails and staples	928	930
Fasteners	1,370	1,340
Chains and parts	119	133
Pipe and tube fittings	161	185
Other	400	475
Total	4,740	5,120
Grand total	37,200	34,300

See footnotes at end of table.

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TABLE 6—Continued
U.S. IMPORTS OF MAJOR IRON AND STEEL PRODUCTS[1]

(Thousand metric tons)

	2004	2005
Cast iron and steel products:		
Cast steel pipe fittings	161	185
Cast iron pipe and fittings	54	64
Other products	396	498
Total	611	744

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: American Iron and Steel Institute.

TABLE 7
U.S. IMPORTS OF STAINLESS STEEL[1]

(Metric tons)

Product	2004	2005
Semifinished	175,000	145,000
Plate	62,300	75,700
Sheet and strip	54,600	51,300
Bars and shapes	84,300	117,000
Wire and wire rods	75,700	75,400
Pipe and tube	108,000	122,000
Total	560,000	585,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: American Iron and Steel Institute.

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TABLE 8
U.S. SHIPMENTS OF IRON AND STEEL CASTINGS

(Thousand metric tons)

	2004	2005
Ductile iron castings	NA	NA
Gray iron castings	NA	NA
Malleable iron castings	NA	NA
Steel castings	NA	NA
Steel investment castings	NA	NA
Total	NA	NA

NA Not available.

Source: U.S. Census Bureau.

TABLE 9
COAL AND COKE AT COKE PLANTS[1, 2]

(Thousand metric tons)

	2004	2005
Coal, consumption	24,100 r	18,700
Coke:[3]		
Production	15,300	15,200
Exports	1,280	1,590
Imports	6,230	3,200
Consumption, apparent	20,400	16,300

rRevised.
[1]Data are rounded to no more than three significant digits.
[2]Includes furnace and merchant coke plants.
[3]Coke production and consumption do not include breeze.

Source: Energy Information Administration, Quarterly Coal Report, DOE/EIA-0121(2006/01Q).

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TABLE 10

PIG IRON AND DIRECT-REDUCED IRON: WORLD PRODUCTION, BY COUNTRY[1, 2, 3, 4]

(Thousand metric tons)

Country[5]	2001	2002	2003	2004	Unrounded 2005[e]
Albania[e]	-- [r]	-- [r]	-- [r]	-- [r]	--
Algeria[e]	1,250,000	1,300,000	1,300,000	994,000 [r, e]	950,000
Argentina:					
Pig iron	1,916,500 [r]	2,180,200 [r]	2,402,200 [r]	2,392,200 [r]	2,645,600 [6]
Direct-reduced iron	1,276,300 [r]	1,475,600 [r]	1,736,400 [r]	1,755,300 [r]	1,820,900 [6]
Australia[e]	7,200,000	7,300,000 [6]	7,300,000 [6]	7,300,000	7,300,000
Austria	4,300,000	4,300,000	4,300,000 [e]	4,300,000 [e]	4,300,000
Belgium	7,732,000	8,053,000	8,000,000	8,000,000 [e]	8,000,000
Bosnia and Herzegovina[e]	60,000 [r]	60,000 [r]	60,000 [r]	60,000 [r]	60,000
Brazil:					
Pig iron	27,623,000	29,667,000 [r]	32,036,000 [r]	34,579,000 [r]	34,382,000 [p]
Direct-reduced iron[e]	400,000	400,000 [6]	410,000 [r]	440,000	411,000
Bulgaria	1,160,000	1,072,000	1,386,000	1,200,000 [r]	1,200,000
Burma:[e]					
Pig iron	1,500	1,500	1,500	1,500	1,500
Direct-reduced iron	40,000	40,000	40,000	40,000	40,000
Canada:					
Pig iron	8,780,000	8,800,000	8,800,000 [e]	8,800,000 [e]	8,800,000
Direct-reduced iron	920,000	920,000	920,000 [e]	920,000 [e]	920,000
Chile	897,000	933,855	987,869	1,137,000 [r]	1,100,000
China[7]	155,540,000	170,850,000	213,660,000	251,850,000	330,410,000 [6]
Colombia	318,993 [r]	312,879 [r]	288,214 [r]	316,025 [r]	315,000
Czech Republic	4,671,000	4,840,000	5,207,000	5,384,000 [r]	5,400,000
Egypt:					
Pig iron[e]	1,400,000	1,800,000	1,500,000	1,500,000	1,500,000
Direct-reduced iron	2,370,000	2,530,000	2,870,000	2,800,000 [e]	2,800,000
Finland	2,852,000	2,828,000	6,000,000 [r]	1,000,000 [r]	2,000,000
France	12,004,000	13,217,000	12,756,000	13,000,000 [e]	13,000,000
Germany:					
Pig iron	29,184,000	29,427,000	29,481,000	30,018,000	28,854,000 [6]
Direct-reduced iron[e]	210,000 [r]	540,000 [r]	590,000 [r]	610,000 [r]	610,000
Hungary	1,226,000	1,335,000	1,333,000	1,351,000 [r]	1,350,000
India:					
Pig iron	21,900,000	24,315,000	24,000,000	25,000,000 [e]	25,500,000
Direct-reduced iron	5,590,000	5,731,000	5,800,000	5,800,000 [e]	5,900,000
Indonesia, direct-reduced iron[e]	1,480,000	1,500,000	1,170,000 [r]	1,440,000 [r]	1,500,000
Iran:					
Pig iron	2,300,000	2,400,000	2,300,000 [e]	2,700,000 [e]	2,300,000
Direct-reduced iron	5,000,000	5,280,000	5,620,000 [e]	6,410,000 [e]	6,850,000
Italy	10,650,000	9,736,000	10,000,000	10,000,000	10,000,000
Japan	78,835,836	80,979,161	82,091,744	82,974,493	83,058,130 [6]
Kazakhstan	3,906,500	4,089,100	4,140,000 [e]	4,283,142 [r]	3,581,090 [6]
Korea, North[e]	800,000	800,000	900,000	900,000	900,000 [6]
Korea, Republic of	25,898,000	26,570,000	27,314,000	27,556,000 [r]	27,308,000 [6]
Libya, direct-reduced iron	1,090,000 [e]	1,170,000	1,340,000 [e]	1,580,000 [e]	1,650,000
Malaysia, direct-reduced iron	1,024,000 [r]	1,061,000 [r]	1,600,000	1,710,000 [r]	1,750,000
Mexico:					
Pig iron	4,373,000	3,996,000	4,183,000	4,278,000	4,047,000 [6]
Direct-reduced iron	3,672,000	4,741,000	5,473,000	6,345,000	5,973,000 [6]

See footnotes at end of table.

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TABLE 10—Continued

PIG IRON AND DIRECT-REDUCED IRON: WORLD PRODUCTION, BY COUNTRY[1, 2, 3, 4]

(Thousand metric tons)

Country[5]	2001	2002	2003	2004	Unrounded 2005[e]
Morocco[e]	15,000	15,000	15,000	15,000	15,000
Netherlands[8]	5,305,000	5,381,000	5,300,000 [e]	5,300,000 [e]	5,300,000
New Zealand[e]	600,000	600,000 [6]	600,000	600,000	600,000
Norway[e]	60,000	80,000	90,000	90,000	90,000
Pakistan[e]	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000
Paraguay	72,000	87,600 [r]	98,000	100,000 [e]	100,000
Peru:					
Pig iron	330,000	330,000	330,000 [e]	330,000 [e]	330,000
Direct-reduced iron[e]	80,000	80,000 [6]	80,000	80,000	80,000
Poland	5,440,000	5,296,000	5,632,000	6,399,000 [r]	6,500,000
Portugal	82,000	100,000 [r]	100,000 [r]	100,000 [r]	100,000
Qatar, direct-reduced iron	730,000	750,000	780,000 [e]	830,000 [e]	830,000
Romania	3,243,000	3,979,000	4,101,000	4,344,000 [r]	4,400,000
Russia:					
Pig iron	44,980,000	46,060,000	48,368,000	50,426,700 [r]	48,419,000 [6]
Direct-reduced iron	2,510,000	2,910,000	2,900,000 [e]	3,140,000 [r, e]	3,340,000
Saudi Arabia, direct-reduced iron	2,880,000	3,290,000	3,290,000	3,141,000 [r]	3,630,000
Serbia and Montenegro	461,000	485,000	635,000	994,000 [r]	950,000
Slovakia	3,255,000	3,533,000	3,892,000	3,765,000 [r]	3,800,000
South Africa:					
Pig iron	5,820,000	5,823,000	6,234,000 [r]	6,011,000 [r]	6,130,000 [6]
Direct-reduced iron	1,556,000	1,702,000	1,542,000	1,630,000 [e]	1,630,000
Spain	4,094,000	3,978,000	4,000,000 [e]	4,000,000 [e]	4,000,000
Sweden	3,614,000	3,703,000	3,700,000 [e]	3,600,000 [e]	3,500,000
Switzerland[e]	100,000	100,000	100,000	100,000 [r]	100,000
Taiwan	10,316,000	10,524,000	10,799,000	10,198,000	10,354,000 [6]
Trinidad and Tobago, direct-reduced iron	2,186,382	2,316,300	2,275,000	2,336,500 [r]	2,340,000
Tunisia	192,000	152,000	36,000	-- [e]	--
Turkey	247,598	157,622	181,080	200,000 [e]	5,950,000
Ukraine	26,400,000	27,560,000	29,570,000	31,000,000	30,747,000
United Kingdom	9,861,000	8,579,000	8,560,500	10,200,000 [e]	10,200,000
United States:					
Pig iron	42,125,000	40,217,287	40,635,545	42,283,000	37,214,000 [6]
Direct-reduced iron	120,000	470,000	210,000	180,000	220,000 [6]
Venezuela, direct-reduced iron	5,903,298	6,824,370	6,645,256	6,800,000	6,900,000
Zimbabwe[e]	156,000	122,000	131,000	72,000	170,000
Grand total	624,085,907 [r]	653,256,474 [r]	711,627,308 [r]	760,489,860 [r]	837,926,220
Of which:					
Pig iron	585,047,927 [r]	609,525,204 [r]	666,335,652 [r]	712,502,060 [r]	788,731,320
Direct-reduced iron	39,037,980 [r]	43,731,270 [r]	45,291,656 [r]	47,987,800 [r]	49,194,900

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Production is pig iron unless otherwise specified.

[3]Direct-reduced iron is obtained from ore by reduction of oxides to metal without melting.

[4]Table excludes ferroalloy production except where otherwise noted. Table includes data available through August 10, 2006.

[5]In addition to the countries listed, Vietnam has facilities to produce pig iron and may have produced limited quantities during 2001-05, but output is not reported and available information is inadequate to make reliable estimates of output levels.

[6]Reported figure.

[7]Figures reported by State Statistical Bureau that the Chinese Government considers to be official statistical data.

[8]Includes blast furnace ferroalloys.

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TABLE 11
RAW STEEL: WORLD PRODUCTION, BY COUNTRY[1, 2, 3]

(Thousand metric tons)

Country[4]	2001	2002	2003	2004	2005[e]
Albania[e]	94	100	100	100	100
Algeria	850	1,091	1,051	1,014	1,007 [5]
Argentina	4,107	4,363	5,033	5,125	5,382 [5]
Australia	7,600	8,242	8,300 [e]	4,811	5,010 [5]
Austria	5,887	6,208	6,261	6,530	7,031 [5]
Bangladesh[e, 6]	30	30	25	25	20
Belarus[e]	1,500 [5]	1,500	1,570	1,900 [r]	2,076 [5]
Belgium	10,783	11,495	11,114	11,698	10,422 [5]
Bosnia and Herzegovina[e]	84	85	90	120 [r]	120
Brazil[7]	26,718	29,605	31,150 [r]	32,918 [r]	31,631 [5]
Bulgaria	1,942	1,860 [e]	2,317 [r]	2,106 [r]	2,200
Burma[e]	25	25	25	25	25
Canada	16,300	16,300	17,000	17,000 [e]	1,700
Chile[7]	1,247	1,279	1,377	1,579 [r]	1,570
China[8]	151,630	182,370	222,340	272,450	349,360 [5]
Colombia	638	664	668	745	750
Croatia	58	34	41 [r]	68 [r]	70
Cuba	270	264	268 [e]	197 [r]	200
Czech Republic	6,316	6,512	6,783 [r]	7,033 [r]	6,200
Denmark	746	392	-- [e]	-- [e]	--
Dominican Republic	33	61	61 [e]	61 [e]	61
Ecuador	60	69	80	72 [r]	72
Egypt	3,800	4,358	4,398	4,757	4,760
El Salvador	39	49 [r]	57	59 [r]	60
Finland	3,938	4,004	4,766	4,833	4,800
France	19,431	20,524	19,578	20,770	19,481 [5]
Germany	44,775	44,999	44,809	46,374	44,524 [5]
Ghana, all from scrap[e]	75	75	75	75	75
Greece	1,281	1,835	1,701	1,967	2,266 [5]
Guatemala	202	216	226	232 [r]	235
Hong Kong[e]	500	500	500	500	500
Hungary	2,056	2,141	2,100 [e]	1,984 [r]	1,946 [5]
India	27,291	28,814	31,779	32,000 [e]	34,000
Indonesia[e]	2,781 [r]	2,462 [r]	2,042 [r]	2,412 [r]	2,800
Iran	6,890	7,293	7,869	9,382	9,400
Iraq[e]	50	--	--	-- [e]	--
Ireland	110	--	-- [e]	-- [e]	--
Israel[e]	220	150	150	280 [r]	300
Italy	26,483	25,930	26,832	28,317	29,061 [5]
Japan	102,866	107,745	110,511	112,718	112,471 [5]
Jordan	30 [e]	134 [r]	135 [r]	140 [r]	140
Kazakhstan	4,691	4,868	5,067	5,400 [e]	4,452 [5]
Korea, North[e]	1,000	1,030	1,090	1,070	1,070
Korea, Republic of	43,852	45,390	46,310	47,521 [r]	47,820 [5]
Latvia	510 [e]	507	546	554 [r]	550
Libya	846 [e]	886	1,007	1,026	1,300
Luxembourg	2,725	2,736	2,675	2,684	2,194 [5]
Macedonia	218	225	291	309 [r]	300
Malaysia	4,100	4,722	3,960	5,698 [r]	6,200

See footnotes at end of table.

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TABLE 11—Continued
RAW STEEL: WORLD PRODUCTION, BY COUNTRY[1, 2, 3]

(Thousand metric tons)

Country[4]	2001	2002	2003	2004	2005[e]
Mauritania[e]	5	5	5	5	5
Mexico	13,300	14,010	15,159	16,730	16,400
Moldova	966	514	886 [r]	1,013 [r]	1,000
Morocco[e]	5	5	5	5	5
Netherlands	6,037	6,144	6,571	6,848	6,919 [5]
New Zealand[e]	770	750	750	800	800
Norway[e]	635 [5]	694	698	695	690
Pakistan[e]	500	500	500	500	500
Paraguay	67 [r]	80 [r]	91 [r]	107 [r]	100
Peru[e]	750	750	750	750	750
Philippines[e]	530	530	340	360	360
Poland	8,809	8,369	9,107 [r]	10,593 [r]	8,514 [5]
Portugal	728	800 [e]	722	720	720
Qatar	908	1,027	1,054	1,046	1,070
Romania	4,930	5,491	5,691 [r]	6,042 [r]	5,854 [5]
Russia	59,030	59,777	62,710	65,646 [r]	66,186 [5]
Saudi Arabia	3,413	3,570 [e]	3,944	3,902	4,190
Serbia and Montenegro	598	596	569 [r]	1,167 [r]	1,286 [5]
Singapore[e]	400	400	400	500 [r]	600
Slovakia	3,676	4,275	4,588 [r]	4,454 [r]	4,482 [5]
Slovenia	462	481 [e]	541 [r]	565 [r]	585
South Africa	8,821	9,095	9,481	9,504	9,492 [5]
Spain	16,500	16,358	16,287	17,684	17,711 [5]
Sri Lanka[e]	30	30	30	30	30
Sweden	5,518	5,754	5,707	5,949	6,000
Switzerland[e]	1,000 [5]	1,000	1,000	1,000	1,000
Syria[e]	70	70	70	70	70
Taiwan	17,336	18,255	18,832	19,604	18,567 [5]
Thailand	2,127	2,538	3,572	4,533 [r]	5,300
Trinidad and Tobago	696	839	923	783 [r]	800
Tunisia	239	200 [e]	86 [e]	63	60
Turkey	14,382	16,046	18,298	20,478	20,960 [5]
Uganda[e]	7	7	7	7	7
Ukraine	33,110	34,538	36,900 [e]	38,740	38,636 [5]
United Arab Emirates[e]	70	70	50	70 [r]	70
United Kingdom	13,610	11,718	13,128	13,766	13,210 [5]
United States	90,100	91,600	93,700	99,700	93,300 [5]
Uruguay	31	35 [r]	41	55 [r]	55
Uzbekistan[e]	460 [5]	450	472	602	607 [5]
Venezuela	3,813	4,164	3,930	4,575	5,000
Vietnam	319	409	544	658	780
Zimbabwe[e]	149	105	152	150	150
Total	853,000	906,000	972,000	1,060,000 [r]	1,120,000

[e]Estimated. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Steel formed in solid state after melting, suitable for further processing or sale; for some countries, includes material reported as "liquid steel," presumably measured in the molten state prior to cooling in any specific form.

[3]Table includes data available through July 28, 2006.

[4]In addition to the countries listed, Mozambique is known to have steelmaking plants, but available information is inadequate to make reliable estimates of output levels.

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TABLE 11—Continued

RAW STEEL: WORLD PRODUCTION, BY COUNTRY[1, 2, 3]

[5]Reported figure.

[6]Data for year ending June 30 of that stated.

[7]Excludes castings.

[8]Figures reported by the State Statistical Bureau that Chinese Government considers as official statistical data.

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IRON AND STEEL SCRAP

By Michael D. Fenton

Domestic survey data and tables were prepared by Steven H. Diamond, statistical assistant.

In 2005, the domestic steel industry recycled or exported for recycling almost 76 million metric tons (Mt) of appliances, automobiles, cans, construction materials, and other steel products. This resulted in an overall recycling rate of nearly 76% (Steel Recycling Institute, 2006c§[1]). Iron and steel scrap is a vital raw material for the production of new steel and cast-iron products. The steelmaking and foundry industries in the United States are highly dependent upon the ready availability of scrap from manufacturing operations and from the recovery of products that are no longer used or needed. The steel industry has been recycling steel scrap for more than 150 years. The Association for Iron and Steel Technology reported that 90 steel-producing plants used electric arc furnaces (EAF), which consumed ferrous scrap, and accounted for about 56% of the total raw steel produced in 2005 (Association for Iron and Steel Technology, 2005).

Steel scrap recycling conserves energy, landfill space, and raw materials. The remelting of scrap requires much less energy than does the production of iron and steel products from iron ore. Each year, steel recycling saves the energy equivalent of the electrical power needed for 1 year by approximately one-fifth of the houses in the United States (about 18 million). Consumption of iron and steel scrap by remelting reduces the burden on landfill disposal facilities and prevents the accumulation of abandoned steel products in the environment. Every metric ton of steel recycled saves 1.134 kilograms (kg) of iron ore, 635 kg of coal, and 54 kg of limestone that would otherwise be consumed to make the iron used in that steel.

In the United States, the primary source of obsolete steel is the automobile (Rich Tavoletti, marketing manager, American Iron and Steel Institute, unpub. data, July 2002). By weight, the typical car consists of about 65% iron and steel. The steel used in car bodies is made of about 25% recycled steel (Steel Recycling Institute, 2006a§). The steel industry recovered and recycled more than 14 Mt of iron and steel automobile scrap in 2005. The recycling rate of automobile scrap steel was 102% in 2005, about the same as that in 2004. A recycling rate greater than 100% is a result of the steel industry recycling more steel from automobiles than was used in the production of new vehicles.

The recycling rate of obsolete appliance scrap had increased to a high of 90% in 2005 from 20% in 1988 (Steel Recycling Institute, 2006c§). During 2005, about 2.75 Mt of steel was recovered from recycled appliances, an increase of nearly 6% compared with that of 2004 (Bill Heenan, president, Steel Recycling Institute, unpub. data, May 6, 2006). The typical appliance consists of about 75% steel, and the steel used in appliances is made with a minimum of 25% recycled steel (Steel Recycling Institute, 2006b§). The recycling rate of steel cans increased to 63% in 2005 from 16% in 1988 (Steel Recycling Institute, 2006c§). The estimated rate of recycling of structural beams and plates in 2004 and 2005 was almost 98%, and that of reinforcement bar and other materials increased to 65% from 63% in 2004. Currently, 2% of homes being built in the United States use 100% steel framing, whereas 10% use some steel framing.

Minimills, in which EAFs are used, consumed greater quantities of direct-reduced iron (DRI) to improve steel quality, and integrated steelmakers continued to use small quantities of DRI in blast furnaces as a process coolant. Minimills often used a feed mix that has equal proportions of DRI, pig iron, and scrap. Raw steel production in the U.S. steel industry decreased by 6.4% during 2005, and DRI production increased by 22% (American Iron and Steel Institute, 2005, p. 76; Midrex Technologies, 2005§).

Environment

Following programs established by Arkansas, Maine, and New Jersey, Virginia's Department of Environmental Quality joined the Virginia Vehicle Recyclers Association to distribute containers to vehicle salvagers for the collection of mercury switches removed from scrapped vehicles (American Metal Market, 2005). Collected switches will be sent to a processing facility in Allentown, PA, for recycling. Each switch contains about 1 gram of mercury, an environmental pollutant that can cause serious neurological health problems, especially in children.

Consumption

Domestic data for ferrous scrap were derived from voluntary monthly or annual surveys of U.S. scrap-consuming operations by the U.S. Geologiccal (USGS). About 38% of the known manufacturers of pig iron and raw steel responded to the surveys. Their responses represented about 48% of estimated total scrap consumption by this class of consumers. The remaining 52% of scrap consumption was estimated based on prior reports. Of the iron foundries, manufacturers of steel castings, and miscellaneous users, about 47% of the surveyed establishments responded to the annual survey, which represented about 57% of estimated scrap consumption. Total consumption for these two classes of consumers was estimated using statistical methods and prior reports. Actual survey data accounted for about 54% of total estimated scrap consumption by all classes of scrap consumers.

In 2005, brokers, dealers, and other outside sources supplied domestic consumers with 50.7 Mt of all types of ferrous scrap at an estimated delivered value of more than $9.8 billion and exported 13.0 Mt (excluding used rails for rerolling and other uses and ships, boats, and other vessels for scrapping) valued at $3.4 billion (tables 1, 8, 11). In 2004, domestic consumers received 53.0 Mt (revised)

[1]References that include a section mark (§) are found in the Internet References Cited section.

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of scrap steel at an estimated delivered value of more than $11.1 billion (revised); exports totaled 11.8 Mt valued at $2.9 billion. This represented a tonnage decrease during 2005 of 4% for received quantities and a tonnage increase of 10% for exported quantities. The value of received scrap grades decreased by 12% and that of exported scrap grades increased by 17% during 2005.

Raw steel production was 93.3 Mt in 2005 compared with 99.7 Mt in 2004 (American Iron and Steel Institute, 2005, p. 75). The share of raw steel produced by electric furnaces was 56% and by the basic oxygen furnaces was 44%. In 2005, continuous cast steel production represented 96% of total raw steel production; this was about the same as that of 2004. Raw steel production capability increased to 120 Mt from 116 Mt in 2004.

Steel mills accounted for 85% of all scrap received from brokers, dealers, and other outside sources; iron foundries and miscellaneous users received 13%; and steel foundries received 2% (table 1). Apparent total domestic consumption of ferrous scrap was 48 Mt of net receipts (total receipts minus shipments) and 15 Mt of home scrap (table 2). Stocks of ferrous scrap at consumer plants decreased by 5% to 5.1 Mt (table 1). Total domestic consumption was more than 65 Mt, which was a 2% decrease compared with that of 2004. The total market for U.S.-produced scrap (net receipts plus exports minus imports) was 59.8 Mt compared with 60.1 (revised) in 2004. Feedstock used in electric furnaces by all iron and steel product manufacturers comprised scrap, 92%; pig iron, 6%; and DRI, 2% (table 4). Total consumption of DRI was 17% greater than that of 2004 (table 1). Net shipments of all grades of steel mill products were about 93.4 Mt, which was a decrease of more than 8% from the 101 Mt shipped in 2004 (American Iron and Steel Institute, 2005, p. 27).

Prices

The average composite delivered price of No. 1 heavy-melting steel scrap, calculated from prices per long ton published monthly by American Metal Market, was $192.44 per metric ton. The price ranged from a low of $122.95 per ton in June to a high of $230.53 per ton in November (table 8). The average composite delivered price of No. 1 heavy-melting steel scrap, calculated from prices per long ton published weekly in Iron Age Scrap Price Bulletin, was $188.51 per ton; the price ranged from a low of $118.92 per ton in June to a high of $228.46 per ton in September.

Based on weekly quotations by Iron Age Scrap Price Bulletin for 18-8 (18% chromium, 8% nickel) stainless steel scrap (bundles and solids) delivered to consumers in the Pittsburgh, PA, area, the average price was $1,487 per ton, about the same as in 2004.

The unit value of total ferrous scrap exports (excluding used rails for rerolling and other uses, and ships, boats, and other vessels for scrapping) increased by 7% to about $265 per ton compared with that of 2004 (table 11). The unit value of total imports, which was about $243 per ton, was about 9% less than that of 2004 (table 14).

Foreign Trade

Foreign trade valuation continued to be reported on a free alongside ship basis for exports and on a customs-value basis for imports. In 2005, the U.S. trade surplus for all classes of ferrous scrap (including used rails for rerolling and other uses and ships, boats, and other vessels for scrapping) was 9.0 Mt valued at $2.49 billion (tables 11, 14). This represented an increase of 29% in quantity and an increase of 51% in value compared with the 2004 surplus of 7.0 Mt valued at $1.65 billion.

Total U.S. exports of carbon steel and cast-iron scrap (excluding alloy steel; ships, boats, and other vessels for scrapping; stainless steel; and used rails for rerolling and other uses) went to 72 countries (2 less than in 2004) and totaled 10.8 Mt (a 13% increase) valued at $2.31 billion (a 17% increase) for an average of $213 per ton (a 3% increase) (U.S. Census Bureau, unpub. data, 2005). The largest tonnages went to China, 3.0 Mt; the Republic of Korea, 1.8 Mt; Mexico, 1.5 Mt; Turkey, 1.5 Mt; and Canada, 1.2 Mt. These five countries received 75% of the total quantity, valued at $1.7 billion, which accounted for 74% of the total value.

Total U.S. exports of stainless steel scrap went to 55 countries (5 more than in 2004) and consisted of 602,466 metric tons (t) (20% more than in 2004) valued at $697 million (a 20% increase) for an average of $1,156 per ton (about the same as that in 2004) (U.S. Census Bureau, unpub. data, 2005). The largest tonnages went to China, 241,801 t; Finland, 70,466 t; Taiwan, 70,454 t, and the Republic of Korea, 55,885 t. These countries received 73% of the total quantity valued at $536 million, which was 77% of the total value.

U.S. exports of alloy steel scrap (excluding stainless steel) were shipped to 43 countries (9 less than in 2004) and consisted of 1.6 Mt (a 13% decrease) valued at $459 million (a 15% increase) for an average of $291 per ton (a 32% increase) (U.S. Census Bureau, unpub. data, 2005). The largest tonnages went to Canada, 916,878 t, and China, 347,498 t. These countries received 80% of the total quantity, valued at $343 million, which accounted for 75% of the total value.

World Review

Iron and steel scrap is an important raw material for the steel and foundry industries. Because scrap comes from such sources as discarded cars and consumer durables, industrial machinery, manufacturing operations, and old buildings, the relatively mature industrialized economies are generally the main exporters of scrap to lesser developed steelmaking countries.

The United States exported the most iron and steel scrap in 2004, followed by Germany, the United Kingdom, Japan, France, and the Netherlands (International Iron and Steel Institute, 2005, p. 72). The six leading significant importing nations were, in decreasing order of importance, Turkey, China, Belgium and Luxembourg, the Republic of Korea, Spain, and Italy (International Iron and Steel Institute, 2005, p. 97).

Outlook

Because of the close interdependence of the steelmaking and ferrous scrap industries, an examination and forecast of the global steel industry in the context of the global economy will serve as the bellwether of the scrap industry.

Growth of the world economy is expected to slow, owing primarily to increasing oil and energy prices. The U.S. gross

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domestic product (GDP) growth was estimated to be less than 3.5% in 2006, down from about 4% in 2005 (Institute for International Economics, 2005§). The International Monetary Fund (IMF) was more optimistic with its world GDP forecast of 4.2% in 2006, down slightly from 4.3% in 2005 (Scrap, 2006).

U.S. GDP growth reported by the U.S. Department of Commerce, Bureau of Economic Analysis (2006§), for 2003, 2004, and 2005 was 2.7%, 4.2%, and 3.5%, respectively. The Council of Economic Advisers, Office of Management and Budget, and the Department of the Treasury forecast faster-than-expected U.S. economic growth in the beginning of 2006, with growth projected to moderate somewhat in the future), owing in part to the rising costs of gasoline and natural gas, and rising interest rates (Lazear, 2006§). GDP growth for 2006 is projected to be 3.6%, and economic strength is broadening, with stronger growth in business investment and exports. The Congressional Budget Office (2006§) projected healthy growth of the U.S. economy during 2006 and 2007. Real GDP was expected to grow by 3.6% in 2006, 3.4% in 2007, an average of 3.1% from 2008 through 2011, and 2.6% from 2012 through 2016. ThyssenKrupp AG (2004§) forecast U.S. GDP growth for 2006 to be 4%. The Organisation for Economic Co-operation and Development (OECD) and the European Confederation of Iron and Steel Industries (Eurofer) forecast the U.S. GDP growth rate to be 3.5% for 2006 (Newratings, 2005§; Metal Center News Online, 2006§). The OECD forecast 3.3% GDP growth in the United States for 2007 (Newratings, 2005§). GDP growth in the United States was expected by the Institute for International Economics (2005§) to decrease to about 2.5% in 2006, down from 3.5% in 2005.

World raw steel production exceeded 1 billion metric tons (Gt) for the first time ever in 2004 and reached 1.13 Gt in 2005 (International Iron and Steel Institute, 2006b§). Global steel production may reach 1.18 Gt in 2007 (MEPS Steel News, 2006§). According to the OECD, global raw steelmaking capacity would increase to more than 1.31 billion metric tons per year (Gt/yr) in 2006 from 1.18 Gt/yr in 2004 (Organisation for Economic Cooperation and Development, 2005§).

The steel market continued strong in 2005, and global apparent steel consumption was forecast to grow to between 1,040 and 1,053 Mt in 2006 from 972 Mt in 2004 (International Iron and Steel Institute, 2005§). Later, the International Iron and Steel Institute (IISI) revised the 2006 figure to 1,087 Mt, and forecast consumption to be 1,150 Mt for 2007 (International Iron and Steel Institute, 2006a§). The IISI forecast steel demand in the United States to grow by 5% in 2006 and by an additional 1.7% in 2007 (International Iron and Steel Institute, 2006a§).

Economic activity in China continued to be an important influence on the world economy and steel markets. With a projected GDP growth in China far greater than that of all other world economies, China is by far the fastest growing economy. However, the explosive growth of China may decrease somewhat after 2005. The IMF forecast growth of 7.5% to 8% in 2005 after 9% to 10% growth in 2004 (Scrap, 2006). The Eurofer projected China's GDP to grow by about 8% in 2006 (Metal Center News Online, 2006§). However, the Chinese Academy of Social Sciences expected the gross national product for 2006 to be 8.9%, down from 9.4% in 2005 (Scrap, 2006); ThyssenKrupp (2004§) forecast growth of 8.5%. China crude steel production was estimated to be about 349 Mt in 2005 and was expected to be about 386 Mt in 2006 (MEPS Steel News, 2006§). The IISI forecast steel demand in China to grow by 13% to 356 Mt in 2006, accounting for 32% of total world steel demand, and 12.1% in 2007 (International Iron and Steel Institute, 2006a§).

The Eurofer forecast 1.9% growth in the European Union's (EU) GDP for 2006, up from 1.4% in 2005 (Metal Center News Online, 2006§). The IISI forecast increases of 3.9% in 2006 and 1.5% in 2007 for the EU; increases of 8.0% during 2006 and 2007 for India; and increases of 3.2% in 2006 and 1.6% in 2007 for in Russia and Ukraine (International Iron and Steel Institute, 2006a§).

World Steel Dynamics (WSD) reported a global shortage of steelmaking metallics, with 2004 requirements up by more than 200 Mt to 1.3 Gt from those of 2000 (American Metal Market, 2004). These metallics comprised pig iron, 713 Mt; obsolete scrap, 315 Mt; new and recirculated scrap, 263 Mt; and scrap substitutes, 58 Mt. WSD predicted that the global metallics requirement could grow to as much as 1.8 Gt/yr by 2015 based on an annual increase of 5.7% in China and 2.3% in the rest of the world. WSD also reported that recovery rates for obsolete scrap outside China were a record 95% in 2004. Thus, the obsolete scrap reservoir is likely to grow by only 1.6% per year through 2015. Yayan (2005§) reported that the IISI had determined that global ferrous scrap production was only 367 Mt, slightly less than consumption of 370 Mt, suggesting that scrap availability would barely meet the steelmaking industry's demand. Nevertheless, as crude steel demand and iron ore prices and shipping costs increase, ferrous scrap prices should remain high, which will be an inducement to collect scrap from new sources in Africa, Asia, Eastern Europe, and the Eastern Mediterranean region.

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TABLE 1

SALIENT U.S. IRON AND STEEL SCRAP, PIG IRON, AND DIRECT-REDUCED IRON STATISTICS[1]

(Thousand metric tons and thousand dollars)

	2001	2002	2003	2004	2005
Manufacturers of pig iron and raw steel and castings:[2]					
Ferrous scrap consumption	56,700 r	56,400 r	55,200 r	57,100 r	54,600
Pig iron consumption	46,900	42,500	39,700	38,000	36,900
Direct-reduced iron consumption	1,780	2,230	1,790	1,490	1,740
Net receipts of ferrous scrap[3]	42,900 r	43,600	42,700 r	45,700 r	43,300
Home scrap production[4]	13,400 r	12,700 r	12,600 r	11,600 r	11,200
Ending stocks of ferrous scrap, December 31	4,330 r	4,360 r	4,070 r	4,880 r	4,440
Manufacturers of steel castings:[5]					
Ferrous scrap consumption	1,560 r	1,900 r	1,130 r	1,310 r	1,810
Pig iron consumption	32	34	31	94	89
Net receipts of ferrous scrap[3]	1,020 r	1,160 r	761 r	972 r	1,060
Home scrap production[4]	519 r	717 r	361 r	326 r	743
Ending stocks of ferrous scrap, December 31	110 r	173 r	88 r	80 r	85
Iron foundries and miscellaneous users:[5]					
Ferrous scrap consumption	11,900	11,200	8,720	8,490	9,020
Pig iron consumption	1,120	1,280	1,030	1,020	1,090
Direct-reduced iron consumption	13	13	4	4	3
Net receipts of ferrous scrap[3]	7,640	7,270	6,300	6,320 r	6,390
Home scrap production[4]	4,250	3,760	2,430	2,370	2,960
Ending stocks of ferrous scrap, December 31	440	401	251	459	605
Total, all manufacturing types:					
Ferrous scrap consumption	70,100 r	69,500 r	65,000 r	66,900 r	65,400
Pig iron consumption	48,000	43,800	40,800	39,100	38,000
Direct-reduced iron consumption	1,800	2,250	1,790	1,500	1,750
Net receipts of ferrous scrap[3]	51,500 r	52,100 r	49,800 r	53,000 r	50,700
Home scrap production[4]	18,200 r	17,200 r	15,400 r	14,300	14,900
Ending stocks, December 31:					
Ferrous scrap at consumer plants	4,880 r	4,930 r	4,410 r	5,420 r	5,130
Pig iron at consumer and supplier plants	787	754	381	722	665
Direct-reduced iron at consumer plants	318	269	345	136	263
Exports:[6]					
Ferrous scrap (includes tinplate and terneplate):[7]					
Quantity	7,440	8,950	10,800	11,800	13,000
Value	1,130,000	1,290,000	1,940,000	2,910,000	3,430,000
Pig iron, all grades:					
Quantity	44	34	86	48	51
Value	5,580	4,910	8,850	6,690	8,110
Direct-reduced iron, steelmaking grade:					
Quantity	1	1	5	13	(8)
Value	83	100	525	1,360	16
Imports for consumption:[6]					
Ferrous scrap (includes tinplate and terneplate):[7]					
Quantity	2,630	3,130	3,480	4,660	3,840
Value	274,000	376,000	511,000	1,230,000	909,000
Pig iron, all grades:					
Quantity	4,370	4,620	3,890	6,400	6,030
Value	479,000	527,000	571,000	1,360,000	1,580,000
Direct-reduced iron, steelmaking grade:					
Quantity	1,650	2,010	1,940	2,450	2,170
Value	145,000	195,000	242,000	463,000	361,000

rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes manufacturers of raw steel that also produce steel castings.

[3]Net receipts of scrap is defined as receipts from brokers, dealers, and other outside sources plus receipts from other company-owned plants minus shipments.

[4]Home scrap production includes recirculating scrap that results from current operations and obsolete home scrap.

[5]Some consumers in the "Manufacturers of steel castings" category also produce iron castings; some consumers in the "Iron foundries and miscellaneous users" category also produce steel castings.

[6]Data from U.S. Census Bureau. Export valuation is free alongside ship, and import valuation is customs value.

[7]Excludes used rails for rerolling and other uses and ships, boats, and other vessels for scrapping.

[8]Less than ½ unit.

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TABLE 2

U.S. CONSUMER RECEIPTS, PRODUCTION, CONSUMPTION, SHIPMENTS, AND STOCKS OF IRON AND STEEL SCRAP IN 2005, BY GRADE[1]

(Thousand metric tons)

Grade	Receipts of scrap		Production of home scrap		Consumption of purchased and home scrap	Shipments of scrap	Ending stocks, December 31
	From brokers, dealers, and other outside sources	From other company-owned plants	Recirculating scrap from current operations	Obsolete scrap[2]			
Manufacturers of pig iron and raw steel and castings:							
Carbon steel:							
Low-phosphorus plate and punchings	305	--	520	--	653	71	134
Cut structural and plate	4,150	132	650	57	4,810	124	266
No. 1 heavy-melting steel	4,160	147	2,080	11	6,320	234	442
No. 2 heavy-melting steel	5,570	66	373	1	6,020	5	420
No. 1 and electric furnace bundles	4,260	63	1,670	30	5,750	112	283
No. 2 and all other bundles	787	13	2	--	828	(3)	42
Electric furnace, 1 foot and under (not bundles)	80	--	83	--	135	47	3
Railroad rails	262	22	42	--	320	--	16
Turnings and borings	2,020	50	44	--	2,200	(3)	100
Slag scrap	853	82	1,460	6	1,990	577	174
Shredded or fragmentized	9,530	1,130	332	112	11,100	70	681
No. 1 busheling	5,150	92	208	72	5,300	(3)	366
Steel cans, post consumer	260	--	44	--	313	--	85
All other carbon steel scrap	1,490	193	1,650	49	3,190	106	305
Stainless steel scrap	731	59	216	--	1,060	1	31
Alloy steel (except stainless)	137	1	498	18	617	7	32
Ingot mold and stool scrap	1	--	80	81	58	82	15
Machinery and cupola cast iron	3	--	2	--	5	--	(3)
Cast-iron borings	298	--	(3)	(3)	302	(3)	18
Motor blocks	8	--	--	--	8	--	1
Other iron scrap	620	81	398	--	1,140	68	380
Other mixed scrap	1,970	72	466	--	2,430	40	643
Total	42,600	2,200	10,800	436	54,600	1,540	4,440
Manufacturers of steel castings:							
Carbon steel:							
Low-phosphorus plate and punchings	283	3	74	(3)	373	(3)	32
Cut structural and plate	154	2	42	(3)	196	(3)	3
No. 1 heavy-melting steel	36	--	4	--	43	--	3
No. 2 heavy-melting steel	17	--	--	--	17	--	(3)
No. 1 and electric furnace bundles	1	--	--	--	1	--	(3)
No. 2 and all other bundles	--	--	--	--	--	--	--
Electric furnace, 1 foot and under (not bundles)	38	--	37	--	75	--	(3)
Railroad rails	19	--	57	--	76	(3)	2
Turnings and borings	34	--	14	(3)	48	(3)	1
Slag scrap	1	--	4	--	5	--	(3)
Shredded or fragmentized	97	--	24	--	121	--	1
No. 1 busheling	75	--	34	--	109	--	2
Steel cans, post consumer	--	--	--	--	--	--	--
All other carbon steel scrap	51	--	97	(3)	146	(3)	4
Stainless steel scrap	20	(3)	30	(3)	52	2	25
Alloy steel (except stainless)	30	2	32	--	62	(3)	7
Ingot mold and stool scrap	(3)	--	(3)	--	(3)	(3)	(3)
Machinery and cupola cast iron	--	--	--	--	--	--	--
Cast-iron borings	--	--	(3)	--	(3)	--	(3)
Motor blocks	--	--	--	--	--	--	--
Other iron scrap	27	--	178	--	206	--	(3)
Other mixed scrap	168	--	101	14	282	1	3
Total	1,050	7	729	14	1,810	3	85

See footnotes at end of table.

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TABLE 2—Continued

U.S. CONSUMER RECEIPTS, PRODUCTION, CONSUMPTION, SHIPMENTS, AND STOCKS OF IRON AND STEEL SCRAP IN 2005, BY GRADE[1]

(Thousand metric tons)

Grade	Receipts of scrap		Production of home scrap		Consumption of purchased and home scrap	Shipments of scrap	Ending stocks, December 31
	From brokers, dealers, and other outside sources	From other company-owned plants	Recirculating scrap from current operations	Obsolete scrap[2]			
Iron foundries and miscellaneous users:							
Carbon steel:							
Low-phosphorus plate and punchings	919	2	163	3	969	23	116
Cut structural and plate	1,160	37	38	(3)	1,240	9	40
No. 1 heavy-melting steel	198	2	16	--	164	(3)	55
No. 2 heavy-melting steel	222	1	--	--	224	(3)	2
No. 1 and electric furnace bundles	90	--	--	--	88	--	4
No. 2 and all other bundles	91	--	24	--	115	3	5
Electric furnace, 1 foot and under (not bundles)	24	--	(3)	--	24	--	1
Railroad rails	65	--	32	--	100	--	3
Turnings and borings	135	--	(3)	--	135	1	2
Slag scrap	--	--	14	--	10	3	1
Shredded or fragmentized	1,310	--	7	--	1,310	8	48
No. 1 busheling	511	(3)	31	(3)	541	1	11
Steel cans, post consumer	12	--	(3)	--	12	--	(3)
All other carbon steel scrap	61	--	2	(3)	63	(3)	3
Stainless steel scrap	2	--	(3)	--	2	(3)	(3)
Alloy steel (except stainless)	1	--	(3)	--	1	(3)	(3)
Ingot mold and stool scrap	56	--	15	--	71	--	10
Machinery and cupola cast iron	617	(3)	251	2	674	32	221
Cast-iron borings	73	37	11	--	118	2	2
Motor blocks	283	3	575	--	855	1	13
Other iron scrap	417	4	1,710	1	2,090	11	64
Other mixed scrap	125	21	59	(3)	204	1	5
Total	6,380	108	2,950	6	9,020	96	605
Grand total, all manufacturing types:							
Carbon steel:							
Low-phosphorus plate and punchings	1,510	5	756	3	2,000	95	282
Cut structural and plate	5,470	171	730	57	6,250	133	310
No. 1 heavy-melting steel	4,390	149	2,100	11	6,520	234	501
No. 2 heavy-melting steel	5,810	68	373	1	6,260	5	422
No. 1 and electric furnace bundles	4,350	63	1,670	30	5,840	112	287
No. 2 and all other bundles	878	13	26	--	944	3	47
Electric furnace, 1 foot and under (not bundles)	142	--	120	--	234	47	4
Railroad rails	345	22	132	--	496	(3)	20
Turnings and borings	2,190	50	59	(3)	2,380	1	102
Slag scrap	854	82	1,470	6	2,010	580	174
Shredded or fragmentized	10,900	1,130	363	112	12,600	78	729
No. 1 busheling	5,730	92	273	72	5,950	1	380
Steel cans, post consumer	272	--	44	--	325	--	85
All other carbon steel scrap	1,600	193	1,740	49	3,400	106	312
Stainless steel scrap	753	59	246	(3)	1,110	2	56
Alloy steel (except stainless)	167	2	531	18	680	7	39
Ingot mold and stool scrap	57	--	96	81	129	82	25
Machinery and cupola cast iron	620	(3)	253	2	679	32	221
Cast-iron borings	371	37	11	(3)	421	2	20
Motor blocks	291	3	575	--	863	1	13
Other iron scrap	1,060	85	2,290	1	3,440	79	444
Other mixed scrap	2,270	93	626	14	2,920	42	651
Total	50,100	2,310	14,500	457	65,400	1,640	5,130

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Obsolete home scrap includes ingot molds, stools, and scrap from old equipment and buildings.

[3]Less than ½ unit.

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TABLE 3
U.S. CONSUMER RECEIPTS, PRODUCTION, CONSUMPTION, SHIPMENTS, AND STOCKS OF PIG IRON AND DIRECT-REDUCED IRON IN 2005[1]

(Thousand metric tons)

	Receipts	Production	Consumption	Shipments	Stocks, December 31
Manufacturers of pig iron, raw steel, and castings:					
Pig iron	6,910 [2]	1,070	36,900	493	614
Direct-reduced iron (DRI)	1,590 [3]	W	1,740	--	262
Manufacturers of steel castings:					
Pig iron	88	(4)	89	(5)	2
DRI	(5)	--	(5)	--	(5)
Iron foundries and miscellaneous users:					
Pig iron	1,080	(4)	1,090	65	49
DRI	3	1	3	--	1
Total, all manufacturing types:					
Pig iron	8,080	31,100	38,000	558	665
DRI	1,590	W	1,750	--	263

W Withheld to avoid disclosing company proprietary data. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes 1.81 million metric tons (Mt) purchased by electric furnace steel producers.
[3]Includes 1.16 Mt purchased by integrated steel producers.
[4]Withheld to avoid disclosing company proprietary data; included in "Total, all manufacturing types."
[5]Less than ½ unit.

TABLE 4
U.S. CONSUMPTION OF IRON AND STEEL SCRAP, PIG IRON, AND DIRECT-REDUCED IRON IN 2005, BY TYPE OF FURNACE OR OTHER USE

(Thousand metric tons)

	Manufacturers of pig iron and raw steel and castings			Manufacturers of steel castings			Iron foundries and miscellaneous users			Total, all manufacturing types		
	Scrap	Pig iron	DRI[2]	Scrap	Pig iron	DRI[2]	Scrap	Pig iron	DRI[2]	Scrap	Pig iron	DRI[2]
Blast furnace	1,380	--	445	--	--	--	3	--	--	1,390	--	445
Basic oxygen process	11,400	34,400	341	--	--	--	--	2	--	11,400	34,400	341
Electric furnace	41,700	2,400	958	1,460	60	(3)	3,390	588	3	46,600	3,040	962
Cupola furnace	40	--	--	353	29	--	5,610	498	--	6,000	528	--
Other[4]	W	--	--	1	(3)	--	W	W	--	W	W	--
Direct castings[5]	--	36	--	--	--	--	--	--	--	--	36	--
Total	54,600	36,900	1,740	1,810	89	(3)	9,010	1,090	3	65,400	38,000	1,750

W Withheld to avoid disclosing company proprietary data; included with "Electric furnace." -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Direct-reduced iron.
[3]Less than ½ unit.
[4]Includes air furnaces.
[5]Includes ingot molds and stools.

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TABLE 5

IRON AND STEEL SCRAP SUPPLY AVAILABLE FOR CONSUMPTION IN 2005, BY REGION AND STATE[1, 2]

(Thousand metric tons)

Region and State	Receipts of scrap		Production of home scrap			
	From brokers, dealers, and other outside sources	From other company-owned plants	Recirculating scrap resulting from current operations	Obsolete scrap[3]	Shipments of scrap[4]	New supply available for consumption
New England and Middle Atlantic:						
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	28	--	10	(5)	(5)	39
New Jersey and New York	2,180	--	118	1	--	2,300
Pennsylvania	3,570	116	2,050	74	24	5,790
Total	5,780	116	2,170	75	24	8,120
North Central:						
Illinois	1,590	53	198	(5)	(5)	1,840
Indiana	3,550	162	3,690	33	497	6,940
Iowa, Nebraska, South Dakota	2,390	13	170	(5)	(6)	2,570
Kansas and Missouri	78	7	61	(5)	(5)	146
Michigan	2,730	13	1,260	295	519	3,780
Minnesota	448	142	41	--	1	630
Ohio	6,370	333	1,870	23	243	8,350
Wisconsin	1,780	2	1,450	1	7	3,230
Total	18,900	725	8,740	352	1,270	27,500
South Atlantic:						
Delaware and Maryland	602	14	385	--	9	992
Florida and Georgia	1,030	--	38	(5)	(5)	1,070
North Carolina and South Carolina	2,470	(6)	220	--	(6)	2,950
Virginia and West Virginia	2,130	(6)	364	(6)	(6)	2,460
Total	6,230	389	1,010	(5)	157	7,470
South Central:						
Alabama and Mississippi	4,560	(6)	752	(6)	19	5,300
Arkansas, Louisiana, Oklahoma	4,530	(6)	334	(6)	(6)	5,010
Kentucky and Tennessee	2,580	95	215	--	(6)	2,870
Texas	3,160	795	508	4	9	4,460
Total	14,800	1,020	1,810	20	45	17,600
Mountain and Pacific:						
Arizona, Colorado, Idaho, Utah	2,320	55	9	(6)	(6)	2,840
California, Oregon, Washington	1,980	W	(5)	(5)	(6)	2,120
Total	4,300	W	9	9	150	4,960
Grand total	50,100	2,260	13,700	451	1,640	65,700

W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Supply available for consumption is a net figure computed by adding production to receipts and deducting scrap shipped during the year. The difference in stock levels at the beginning and end of the year is not taken into consideration.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Obsolete scrap includes ingot molds, stools, and scrap from old equipment, buildings, etc.

[4]Includes scrap shipped, transferred, or otherwise disposed of during the year.

[5]Less than ½ unit.

[6]Withheld to avoid disclosing company proprietary data; included in "Total" or "Grand total."

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TABLE 6
U.S. CONSUMPTION OF IRON AND STEEL SCRAP AND PIG IRON IN 2005, BY REGION AND STATE[1, 2, 3]

(Thousand metric tons)

Region and State	Manufacturers of pig iron and raw steel and castings		Manufacturers of steel castings		Iron foundries and miscellaneous users		Total, all manufacturing types	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
New England and Middle Atlantic:								
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont	1,780	22	11	--	652	155	2,440	177
Pennsylvania	5,510	2,860	170	1	340	31	6,020	2,900
Total	7,290	2,890	181	1	992	186	8,460	3,070
North Central:								
Illinois	1,360	2,020	68	1	308	14	1,740	2,040
Indiana	5,900	12,100	64	1	861	86	6,830	12,200
Iowa, Kansas, Minnesota, Missouri, Nebraska, South Dakota, Wisconsin	2,850	1	1,080	62	2,370	419	6,310	481
Michigan	1,660	4,670	27	--	1,360	95	3,040	4,770
Ohio	7,250	6,860	184	(4)	626	144	8,060	7,010
Total	19,000	25,700	1,430	64	5,520	758	26,000	26,500
South Atlantic:								
Delaware, Maryland, Virginia, West Virginia	3,490	W	W	W	304	16	3,790	1,600
Florida, Georgia, North Carolina, South Carolina	4,020	W	W	W	155	2	4,170	182
Total	7,500	1,760	2	(4)	459	18	7,960	1,780
South Central:								
Alabama, Kentucky, Mississippi, Tennessee	6,650	W	85	W	1,610	W	8,350	4,260
Arkansas, Louisiana, Oklahoma	5,070	W	12	W	18	W	5,100	804
Texas	4,320	52	10	W	185	24	4,520	101
Total	16,000	5,010	107	24	1,820	129	18,000	5,170
Mountain and Pacific:								
Arizona, Colorado, Idaho, Utah	2,760	W	6	(4)	106	W	2,880	1,500
California, Oregon, Washington	1,970	W	89	(4)	120	W	2,180	3
Total	4,740	1,500	94	(4)	226	4	5,060	1,510
Grand total	54,600	36,900	1,810	89	9,020	1,090	65,400	38,000

W Withheld to avoid disclosing company proprietary data; included in "Total" or "Grand total." -- Zero.
[1]Includes recirculating scrap resulting from current operations and home-generated obsolete scrap.
[2]Includes molten pig iron used for ingot molds and direct castings.
[3]Data are rounded to no more than three significant digits; may not add to totals shown.
[4]Less than ½ unit.

TABLE 7
U.S. CONSUMER STOCKS OF IRON AND STEEL SCRAP AND PIG IRON, DECEMBER 31, 2005, BY REGION AND STATE[1]

(Thousand metric tons)

Region and State	Carbon steel[2]	Stainless steel	Alloy steel[3]	Cast iron[4]	Other grades of scrap	Total scrap	Pig iron
New England and Middle Atlantic:							
Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont	(5)	(5)	--	(5)	W	1	(5)
New Jersey and New York	56	1	1	2	W	59	(5)
Pennsylvania	241	15	16	16	5	293	10
Total	297	16	17	18	5	353	10

See footnotes at end of table.

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TABLE 7—Continued
U.S. CONSUMER STOCKS OF IRON AND STEEL SCRAP AND PIG IRON, DECEMBER 31, 2005, BY REGION AND STATE[1]

(Thousand metric tons)

Region and State	Carbon steel[2]	Stainless steel	Alloy steel[3]	Cast iron[4]	Other grades of scrap	Total scrap	Pig iron
North Central:							
Illinois	122	(5)	W	81	2	205	18
Indiana	421	5	W	16	22	465	153
Iowa, Kansas, Missouri, Nebraska, South Dakota	101	(5)	(5)	8	--	109	5
Michigan	122	(5)	1	12	17	152	9
Minnesota and Wisconsin	54	2	3	4	(5)	64	3
Ohio	564	31	8	182	--	784	30
Total	1,380	39	13	303	41	1,780	219
South Atlantic:							
Delaware, Maryland, Virginia, West Virginia	174	(5)	W	92	14	280	54
Florida, Georgia, North Carolina, South Carolina	263	(5)	W	14	1	278	41
Total	437	(5)	(5)	106	15	558	94
South Central:							
Alabama, Kentucky, Mississippi, Tennessee	635	W	W	277	W	1,410	170
Arkansas, Louisiana, Oklahoma	437	W	W	1	W	439	129
Texas	246	W	W	6	W	254	32
Total	1,320	(5)	6	284	494	2,100	331
Mountain and Pacific:							
Arizona, Colorado, Idaho, Utah	149	(5)	W	5	64	218	W
California, Oregon, Washington	72	2	W	7	31	114	W
Total	220	2	3	12	95	332	10
Grand total	3,660	56	39	724	651	5,130	665

W Withheld to avoid disclosing company proprietary data; included in "Total" or "Grand total." -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Excludes rerolling rails.
[3]Excludes stainless steel.
[4]Includes borings.
[5]Less than ½ unit.

TABLE 8
U.S. AVERAGE MONTHLY PRICE AND COMPOSITE PRICE FOR NO. 1 HEAVY-MELTING STEEL, WITH ANNUAL AVERAGES[1]

(Dollars per metric ton)

Period	Chicago, IL	Philadelphia, PA	Pittsburgh, PA	Composite price
2004, average	216.80	197.02	217.51	210.45
2005:				
January	199.79	197.38	208.16	201.78
February	187.00	197.41	204.09	196.17
March	187.00	200.01	197.06	194.69
April	213.71	214.23	214.66	214.20
May	178.09	176.78	177.16	177.34
June	122.36	127.95	118.55	122.95
July	133.36	138.03	134.84	135.41
August	186.78	183.02	185.54	185.12
September	237.38	212.45	228.90	226.24
October	201.06	195.86	200.49	199.14
November	242.36	203.44	245.81	230.53
December	238.60	196.84	241.60	225.68
Average	193.96	186.95	196.40	192.44

[1]Calculated by the U.S. Geological Survey from prices published in American Metal Market.

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TABLE 9
U.S. EXPORTS OF IRON AND STEEL SCRAP, BY COUNTRY[1, 2]

(Thousand metric tons and thousand dollars)

Country	2004		2005	
	Quantity	Value	Quantity	Value
Bahamas, The	2	387	2	462
Bangladesh	6	1,150	28	7,320
Belgium	23	3,020	13	3,710
Brazil	2	757	10	2,410
Canada	2,170	236,000	2,160	264,000
Chile	2	245	1	177
China	2,970	923,000	3,530	1,260,000
Colombia	4	463	51	11,900
Dominican Republic	2	1,370	1	192
Egypt	55	12,100	208	52,500
Finland	72	99,800	65	97,900
France	1	1,050	4	4,610
Germany	17	7,620	7	3,260
Greece	1	115	23	4,310
Guatemala	30	5,660	(3)	202
Hong Kong	72	41,400	49	31,200
India	295	90,800	806	221,000
Indonesia	41	11,700	188	46,200
Ireland	1	565	1	549
Italy	150	40,400	137	36,900
Japan	93	41,100	41	28,700
Kenya	59	24,700	71	12,800
Korea, Republic of	1,880	490,000	1,130	316,000
Malaysia	399	80,700	457	109,000
Mexico	1,510	305,000	1,500	287,000
Netherlands	15	16,100	21	18,300
Pakistan	4	770	39	10,300
Panama	3	789	(3)	43
Peru	186	39,500	44	10,000
Portugal	25	4,750	21	4,120
Qatar	(3)	22	31	6,560
Saudi Arabia	(3)	116	32	7,220
Singapore	15	4,610	75	2,130
Slovenia	21	5,160	--	--
Spain	10	13,200	18	15,100
Sweden	1	2,280	7	5,640
Switzerland	3	1,120	(3)	283
Taiwan	191 r	93,700	283	153,000
Thailand	751	150,000	337	77,500
Turkey	631	136,000	1,500	299,000
Turks and Caicos Islands	7	780	2	176
United Arab Emirates	5	1,440	3	688
United Kingdom	24	8,240	9	6,080
Venezuela	4	694	6	1,540
Vietnam	13	3,830	26	7,570
Other	10 r	3,040 r	17	5,670
Total	11,800	2,910,000	13,000	3,430,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Excludes used rails for rerolling and other uses and ships, boats, and other vessels for scrapping. Export valuation is free alongside ship. The United States exported scrap to 87 countries in 2004 and 101 countries in 2005.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 10
U.S. EXPORTS OF IRON AND STEEL SCRAP, BY CUSTOMS DISTRICT[1, 2]

(Thousand metric tons and thousand dollars)

Customs district	2004		2005	
	Quantity	Value	Quantity	Value
Baltimore, MD	18	9,430	37	18,900
Boston, MA	794	176,000	682	154,000
Buffalo, NY	111	29,700	114	33,200
Charleston, SC	83	22,200	53	32,500
Charlotte, NC	24	6,380	28	8,970
Chicago, IL	9	4,510	3	1,800
Cleveland, OH	1	713	1	366
Columbia-Snake River, OR/WA	403	98,200	325	78,700
Detroit, MI	329	61,000	411	78,000
Duluth, MN	44	8,650	52	6,530
El Paso, TX	3	691	6	1,390
Great Falls, MT	23	3,280	28	4,650
Honolulu, HI	125	29,300	147	35,900
Houston-Galveston, TX	127	83,600	101	48,500
Laredo, TX	417	88,700	898	162,000
Los Angeles, CA	2,100	653,000	2,820	934,000
Miami, FL	46	18,900	50	41,100
Mobile, AL	4	4,320	24	9,730
New Orleans, LA	69	97,800	304	125,000
New York, NY	1,730	480,000	1,920	545,000
Nogales, AZ	20	2,970	1	217
Norfolk, VA	137	41,500	116	61,200
Ogdensburg, NY	63	12,600	69	14,900
Pembina, ND	510	78,800	596	93,600
Philadelphia, PA	418	91,600	592	124,000
Portland, ME	288	61,000	185	42,300
Providence, RI	252	48,800	215	44,500
San Diego, CA	200	27,200	114	16,400
San Francisco, CA	1,220	306,000	1,110	326,000
San Juan, PR	80	15,300	55	11,700
Savannah, GA	66	36,400	83	47,100
Seattle, WA	632	192,000	712	237,000
St. Albans, VT	51	9,840	59	12,300
Tampa, FL	321	65,400	222	46,600
Other	1,050	39,900	817	33,600
Total	11,800	2,910,000	13,000	3,430,000

[1]Excludes used rails for rerolling and other uses and ships, boats, and other vessels for scrapping. Export valuation is free alongside ship.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 11
U.S. EXPORTS OF IRON AND STEEL SCRAP, BY GRADE[1, 2]

(Thousand metric tons and thousand dollars)

Grade	2004		2005	
	Quantity	Value	Quantity	Value
No. 1 heavy-melting scrap	1,970	406,000	3,180	617,000
No. 2 heavy-melting scrap	406	79,900	325	65,900
No. 1 bundles	301	38,100	330	35,500
No. 2 bundles	45	7,790	91	21,300
Shredded steel scrap	3,710	778,000	3,800	834,000
Borings, shovelings, and turnings	207	20,000	241	27,200
Cut plate and structural	547	115,000	387	87,700
Tinned iron or steel	82	19,200	77	24,900
Remelting scrap ingots	7	6,270	10	8,900
Stainless steel scrap	478	548,000	585	670,000
Other alloy steel scrap	1,740	387,000	1,570	455,000
Other steel scrap[3]	1,260	300,000	1,240	328,000
Iron scrap	1,030	201,000	1,120	255,000
Total	11,800	2,910,000	13,000	3,430,000
Ships, boats, and other vessels for scrapping	16	2,680	3	476
Used rails for rerolling and other uses[4]	42	18,100	55	25,600
Grand total	11,800	2,930,000	13,000	3,460,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Export valuation is free alongside ship.
[3]Includes tinplate and terneplate.
[4]Includes mixed (used plus new) rails. More information can be found in table 15.

Source: U.S. Census Bureau.

TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF IRON AND STEEL SCRAP, BY COUNTRY[1, 2]

(Thousand metric tons and thousand dollars)

Country	2004		2005	
	Quantity	Value	Quantity	Value
Argentina	(3)	681	(3)	201
Aruba	7	1,610	--	--
Bahamas, The	5	275	3	351
Belgium	3	14,700	36	9,780
Brazil	5	1,540	1	774
Canada	2,550	591,000	2,750	570,000
China	2	1,100	2	978
Colombia	1	1,160	1	118
Denmark	138	31,600	--	--
Dominican Republic	76	16,400	31	6,900
Ecuador	1	712	(3)	102
Egypt	1	1,070	1	732
Finland	2	5,250	1	93
France	(3)	60	(3)	358
Germany	7	1,130	2	148
Italy	(3)	29	(3)	72
Japan	2	807	1	1,540
Malaysia	--	--	2	264
Mexico	126	57,700	145	61,000
Netherlands	247	79,100	222	72,300
Netherlands Antilles	17	1,630	--	--
Russia	86	30,700	35	10,500
South Africa	3	2,070	4	35
Suriname	3	445	--	--
Sweden	313	76,300	261	71,500
Taiwan	30	419	1	396

See footnotes at end of table.

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TABLE 12—Continued
U.S. IMPORTS FOR CONSUMPTION OF IRON AND STEEL SCRAP, BY COUNTRY[1, 2]

(Thousand metric tons and thousand dollars)

Country	2004		2005	
	Quantity	Value	Quantity	Value
Trinidad and Tobago	10	2,630	1	647
United Arab Emirates	(3)	16	(3)	170
United Kingdom	1,020	300,000	338	97,200
Venezuela	9	8,360	1	1,560
Other	3	1,970	2	1,700
Total	4,660	1,230,000	3,840	909,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Excludes used rails for rerolling and other uses and ships, boats, and other vessels for scrapping. Import valuation is customs value. The United States imported scrap from 50 countries in 2004 and 43 countries in 2005.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF IRON AND STEEL SCRAP, BY CUSTOMS DISTRICT[1, 2]

(Thousand metric tons and thousand dollars)

Customs district	2004		2005	
	Quantity	Value	Quantity	Value
Baltimore, MD	1	365	(3)	213
Buffalo, NY	454	179,000	423	152,000
Charleston, SC	1,110	309,000	869	253,000
Charlotte, NC	21	5,500	--	--
Chicago, IL	45	2,720	20	1,880
Cleveland, OH	23	350	11	665
Detroit, MI	1,220	272,000	1,450	280,000
Duluth, MN	26	6,920	39	8,640
El Paso, TX	31	8,410	32	6,970
Great Falls, MT	18	3,350	12	2,120
Houston-Galveston, TX	27	18,500	18	17,900
Laredo, TX	34	27,400	34	23,600
Los Angeles, CA	2	1,770	2	1,580
Miami, FL	2	236	(3)	112
Mobile, AL	195	49,100	56	12,000
New Orleans, LA	741	229,000	95	23,300
New York, NY	3	1,500	3	552
Nogales, AZ	9	2,860	11	3,640
Ogdensburg, NY	28	15,100	16	9,520
Pembina, ND	78	23,300	72	20,700
Philadelphia, PA	(3)	86	1	348
Portland, ME	1	105	(3)	11
San Diego, CA	46	10,200	55	13,200
Savannah, GA	30	414	1	322
Seattle, WA	514	62,200	618	75,700
Tampa, FL	4	261	3	324
Other	1	1,020	2	1,280
Total	4,660	1,230,000	3,840	909,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Excludes used rails for rerolling and other uses and ships, boats, and other vessels for scrapping. Import valuation is customs value.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 14
U.S. IMPORTS FOR CONSUMPTION OF IRON AND STEEL SCRAP, BY CLASS[1, 2]

(Thousand metric tons and thousand dollars)

Class	2004		2005	
	Quantity	Value	Quantity	Value
No. 1 heavy-melting scrap	118	20,300	55	7,010
No. 2 heavy-melting scrap	27	3,880	46	7,160
No. 1 bundles	910	251,000	879	228,000
No. 2 bundles	1	105	10	3,340
Shredded steel scrap	1,340	299,000	841	187,000
Borings, shovelings, and turnings	58	5,680	95	8,340
Cut plate and structural	125	19,600	193	35,300
Tinned iron or steel	10	2,020	17	3,160
Remelting scrap ingots	31	1,230	2	1,080
Stainless steel scrap	146	160,000	111	124,000
Other alloy steel scrap	291	77,500	425	81,200
Other steel scrap[3]	1,270	327,000	780	161,000
Iron scrap	338	63,300	385	62,700
Total	4,660	1,230,000	3,840	909,000
Ships, boats, and other vessels for scrapping	(4)	128	(4)	208
Used rails for rerolling and other uses[5]	131	44,100	164	62,800
Grand total	4,790	1,280,000	4,000	972,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Import valuation is customs value.
[3]Includes tinplate and terneplate.
[4]Less than ½ unit.
[5]Includes mixed (used plus new) rails. More information can be found in table 16.

Source: U.S. Census Bureau.

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TABLE 15

U.S. EXPORTS OF USED RAILS FOR REROLLING AND OTHER USES, BY COUNTRY[1, 2]

Country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Argentina	1	$13	1	$3
Aruba	--	--	3	47
Australia	559	859	470	1,040
Austria	12	61	8	35
Bahamas, The	24	98	268	202
Brazil	11	29	679	531
Canada	17,600	5,890	20,200	9,100
Cayman Islands	49	36	102	120
Chile	88	104	21	43
China	1,020	300	612	205
Colombia	192	74	264	76
Dominican Republic	472	256	519	573
Egypt	--	--	2,120	1,020
El Salvador	5	8	1	11
France	28	114	42	19
Georgia	6	19	--	--
Germany	66	252	50	10
Grenada	41	59	--	--
Guatemala	--	--	93	34
Hong Kong	11	149	16	297
Ireland	--	--	1	119
Italy	18	13	1	24
Japan	3	44	11	167
Korea, Republic of	77	69	65	148
Malaysia	23	41	--	--
Mexico	19,500	8,320	26,900	10,100
New Caledonia	10	15	--	--
New Zealand	(3)	5	44	120
Peru	10	3	228	170
Philippines	1	4	2	3
Portugal	17	29	--	--
Saudi Arabia	36	99	1	24
Singapore	1	7	5	27
Slovakia	--	--	17	5
Spain	--	--	54	11
Suriname	--	--	14	8
Sweden	2	14	--	--
Taiwan	1,750	552	2,420	978
Thailand	5	56	9	17
Turks and Caicos Islands	11	163	21	157
United Arab Emirates	212	154	--	--
United Kingdom	59	118	33	30
Venezuela	7	30	22	87
Other	4 r	82 r	13	69
Total	41,900	18,100	55,300	25,600

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Exports contain mixed (used plus new) rails totaling 13,500 metric tons (t) valued at $10,100,000 in 2004 and 21,500 t valued at $15,600,000 in 2005. Export valuation is free alongside ship value.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 16
U.S. IMPORTS FOR CONSUMPTION OF USED RAILS FOR REROLLING AND OTHER USES, BY COUNTRY[1, 2]

Country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Austria	3	$3	447	$500
Brazil	1 r	6	--	--
Canada	29,000	7,210	29,000	8,700
Czech Republic	--	--	6	12
Germany	341	455	531	837
Italy	--	--	2	6
Japan	2	4	72	15
Korea, Republic of	9	8	110	74
Mexico	2	5	619	410
Netherlands	17	22	--	--
Philippines	2	6	--	--
Russia	85,700	33,400	109,000	46,100
Spain	99	46	--	--
Switzerland	--	--	(3)	3
Taiwan	18	27	2	5
Ukraine	15,500	2,950	23,700	6,190
United Kingdom	2	4	21	34
Total	131,000 r	44,100	164,000	62,800

rRevised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Import valuation is customs value.
[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 17
U.S. EXPORTS OF DIRECT-REDUCED IRON, BY COUNTRY[1, 2]

Country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Brazil	47	$5	--	--
Canada	116	13	--	--
China	12,000	1,280	--	--
Colombia	43	4	--	--
Mexico	503	53	87	$9
Spain	33	3	68	7
Turkey	36	4	--	--
Total	12,800	1,360	155	16

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Data are for steelmaking-grade direct-reduced iron only.

Source: U.S. Census Bureau.

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TABLE 18
U.S. IMPORTS FOR CONSUMPTION OF DIRECT-REDUCED IRON, BY COUNTRY[1, 2]

Country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Brazil	--	--	238,000	$17,900
Canada	435,000	$45,300	532,000	50,300
China	--	--	425	53
Italy	709	75	--	--
Russia	64,000	16,100	--	--
Trinidad and Tobago	220,000	58,100	92,100	20,300
United Kingdom	62,500	15,600	--	--
Venezuela	1,670,000	328,000	1,310,000	272,000
Total	2,450,000	463,000	2,170,000	361,000

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Data are for steelmaking-grade direct-reduced iron only.

Source: U.S. Census Bureau.

TABLE 19
U.S. EXPORTS OF PIG IRON, BY COUNTRY[1, 2]

Country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Brazil	--	--	13	$6
Canada	5,910	$1,240	9,010	1,430
Cayman Islands	--	--	907	80
China	479	48	5	9
Colombia	18,400	1,620	21,000	1,850
Costa Rica	--	--	472	42
Czech Republic	47	4	--	--
Dominican Republic	--	--	154	65
France	--	--	1,660	151
Germany	36	17	31	14
Italy	77	19	--	--
Jamaica	270	24	--	--
Korea, Republic of	631	109	895	94
Malaysia	--	--	322	28
Mexico	15,200	1,800	13,900	4,100
Netherlands	30	3	14	7
Singapore	42	8	--	--
Switzerland	15	7	--	--
Taiwan	101	12	956	84
Trinidad and Tobago	--	--	271	24
Turkey	6,690	1,780	--	--
United Arab Emirates	--	--	948	83
United Kingdom	20	9	59	31
Venezuela	--	--	19	9
Total	48,000	6,690	50,700	8,110

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes the following grades of pig iron: less than or equal to 0.5% phosphorus content, greater than 0.5% phosphorus content, and alloy grade. Export valuation is free alongside ship value.

Source: U.S. Census Bureau.

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TABLE 20
U.S. IMPORTS FOR CONSUMPTION OF PIG IRON, BY COUNTRY[1, 2]

Country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Argentina	--	--	27,200	$7,210
Australia	--	--	204	214
Brazil	4,770,000	$914,000	4,460,000	1,180,000
Canada	95,200	25,000	105,000	34,000
China	132,000	31,200	57,200	13,900
Colombia	--	--	238	147
Germany	--	--	10	3
Hong Kong	--	--	3	5
Italy	--	--	498	236
Japan	1	3	--	--
Mexico	--	--	27	15
Russia	1,110,000	314,000	918,000	218,000
South Africa	118,000	23,900	141,000	44,000
Trinidad and Tobago	48,400	14,300	26,200	816
Ukraine	80,200	18,700	274,000	76,700
United Kingdom	15,300	4,520	--	--
Venezuela	28,300	10,100	22,400	988
Total	6,400,000	1,360,000	6,030,000	1,580,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes the following grades of pig iron: less than or equal to 0.5% phosphorus content, greater than 0.5% phosphorus content, and alloy grade. Import valuation is customs value.

Source: U.S. Census Bureau.

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IRON ORE

By John D. Jorgenson

Domestic survey data and tables were prepared by Amy C. Tolcin, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

U.S. iron ore production decreased slightly in 2005 compared with that of 2004; consumption decreased by 7%. World iron ore production and consumption again rose in 2005. Brazil was the leading producer of iron ore in terms of iron content, while China led gross tonnage production and was by far the leading consumer (tables 1, 16). World iron ore trade increased for the third consecutive year and prices continued to rise, although not as dramatically as in 2004.

The supply of iron ore—the basic raw material from which iron and steel are made—is critical to the United States and all industrialized nations. Scrap can be considered to be a supplement to iron ore in the steelmaking process but is limited as a major feed material owing to inadequate supply of high-quality scrap. Direct reduced iron (DRI), which is used as an alternative to scrap, requires iron ore for its production.

Hematite (Fe_2O_3) and magnetite (Fe_3O_4), both iron oxides, are the primary commercial minerals of iron ore. Taconite, which contains hematite and magnetite in varying proportions, is the principal iron ore mined in the United States. It is found in hard, fine-grained banded iron formations with low (20% to 30%) iron content. Almost 99% of domestic iron ore production is transformed into molten iron in a blast furnace by the iron and steel industry. The molten iron can go directly to a basic oxygen furnace (BOF) where it is converted to steel by removing most of the remaining carbon or be used in molds to produce pig iron.

In 2005, the United States consumed 60.1 million metric tons (Mt) of iron ore, a decrease of 4.4 Mt compared with that of 2004, and produced 37.2 Mt of pig iron. Pig iron production was at the lowest level since just prior to the Second World War.

Raw steel production at 95 Mt decreased by 5% compared with that of 2004. U.S. steel consumption decreased to 109 Mt from 117 Mt in 2004. Domestically produced iron ore is supplemented with imported iron ore to produce pig iron, which is used along with imported pig iron, DRI, and scrap to produce raw steel. This raw steel is used along with imported raw steel to produce steel mill products. Integrated steel mills produce steel from iron ore; minimills produce steel from DRI and scrap. In 2005, the minimill sector of the steel industry produced 55% of the raw steel in the United States.

Imports of pig iron and semifinished steel allow integrated steelmakers to increase steel shipments without increasing blast furnace production, thus avoiding major production increases, which require restarting blast furnaces and employing additional skilled workers. Iron ore substitutes can be used to help the highly cyclical steel industry avoid the shutdown of blast furnaces and layoffs of production workers when demand for steel falls. In 2005, net U.S. imports of iron ore substitutes were 5.1 Mt, an almost 40% decrease compared with their tonnage for 2004, owing mainly to an increase in net exports of 28% for scrap and decreases in net imports of 8% in semifinished steel products, 6% in pig iron, and 11% in DRI. During the year, a 5% decrease in raw steel production coupled with a 7% fall in steel demand resulted in iron ore consumption falling 7% from 2004 levels.

Legislation and Government Programs

The Governor of Minnesota reaffirmed his administration's commitment to such Iron Range economic development projects as Minnesota Steel Industries, LLC's (MSI) steelmaking project in Nashwauk and the Mesabi Nugget project at Silver Bay. Local press reported that $49 million, or most of the seed money for these projects, had been removed from the 21st Century Minerals Fund to help resolve State deficit problems (Hanna, 2005§[1]).

Progress continued on this MSI project to develop a taconite mine, pelletizing plant, and DRI plant at a steelmaking complex on the Mesabi Iron Range. MSI realigned the concept from a hot-rolled coil product to steel slab, an intermediary product, and submitted an environmental assessment worksheet; also completed was a final scoping decision document. MSI tentatively planned to issue a final environmental impact statement in 2006 for the $1.6 billion project, which was to produce 2.5 million metric tons per year (Mt/yr) of slab steel (Leonard, 2005§; Minnesota Steel Industries, LLC, 2005§).

The Minnesota Pollution Control Agency (PCA) citizen's board decided in favor of Cleveland-Cliffs Inc (Cliffs) and United States Steel Corporation (U.S. Steel) on two separate issues. The PCA decided to allow Cliffs' Northshore plant at Silver Bay, MN, to increase taconite pellet capacity by 1.4 Mt/yr. The planned $29 million project would include the restart of two fine crushers, several concentrator lines, and one furnace. The PCA also declared U.S. Steel's environmental impact assessment adequate for the Minntac Mine's tailing disposal basin near Mountain Iron, MN. This will allow U.S. Steel, in conjunction with agency staff, to develop a permit for a water management plan to handle the 250,000 gallons per minute needed for processing iron ore. The current water management system has become increasingly congested with solids, making it difficult to process and recycle all of the water (Skillings Mining Review, 2005b).

The Minnesota legislature published a bill that defined commercial production of direct reduced ore for purposes of the State's taconite production tax as greater than 50,800 metric tons per year (t/yr) (50,000 long tons per year). A subsequent, supplemental legislative bulletin further defined commercial and noncommercial production of direct reduced ore and set forth weighting factors for the occupation tax. Effective for taxes payable in 2006, the production tax, although not imposed on noncommercial production of direct reduced ore, is required

[1]References that include a section mark (§) are found in the Internet References Cited section.

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on taconite or iron sulfides consumed in the production of noncommercial direct reduced ore. Effective January 1, 2007, the weighting of the occupancy tax will be 75% sales, 12.5% property, and 12.5% payroll factors (Minnesota Department of Revenue, 2005a§, b§).

Production

The U.S. Geological Survey (USGS) develops U.S. iron ore production data through an annual "Iron Ore" survey, which provided 100% of production listed in tables 1 through 4. This information is supplemented by employment data, mine inspection reports, and information from consumers. The American Iron Ore Association no longer provides data on ore shipments from loading docks on the Upper Great Lakes nor receipts at transfer docks and furnace yards nationwide. The dock and steel plant data are compiled by the American Iron and Steel Institute (AISI).

Domestic iron ore production at 54.3 Mt in 2005 decreased slightly from 2004 production of 54.7 Mt. Michigan and Minnesota taconite mines accounted for almost all domestic iron ore production. Six of these mines operated on the Mesabi Range in northeastern Minnesota, and two, on the Marquette Range in the Upper Peninsula of northwestern Michigan. Domestic iron ore supply (production minus exports) met 71% of domestic demand in 2005, about the same as the average from 2002 through 2004.

Ispat Inland Mining Company (a subsidiary of Mittal Steel Corporation) announced plans to open at least two new iron ore pits near Biwabik and McKinley in northern Minnesota. Without development of the new pits, Ispat's reserves were expected to be exhausted in 8 years. If the new pits are approved, mining could begin as early as January 2007 (WCCO-TV, 2005§).

Additional demand for iron ore pellets was expected when U.S. Steel finishes rebuilding its renamed No. 14 blast furnace at the company's steelworks in Gary, IN. The rebuild, planned to raise the blast furnace capacity by 30% and increase availability to 97.5%, was expected to be completed in the first quarter of 2006 (United States Steel Corporation, 2005§, 2006§).

Cliffs announced that its 2005 operating income had tripled compared with that of 2004. Cliffs' share of 2005 production from its North American operations, including Wabush operations in Canada, was 23.3 Mt, an increase of 2% compared with that of 2004 (Cleveland-Cliffs Inc, 2006b§). Operating income increased despite higher operating costs. Fuel costs were substantially higher than projected in an industry that is very fuel-intensive. Minnesota iron ore mines, which had consumed more than 24 million gallons (91 million liters) of diesel fuel in 2003, were seriously affected by prices as high as 55 cents per gallon greater than projected for 2005. Overall production costs were also affected by a worldwide shortage of heavy-equipment tires, which are made by only three manufacturers. Tire shortages were exacerbated by recent expansions in the world mining industry and increased demand for large tires by China (Bloomquist, 2005a§, b§).

Michigan.—Michigan accounted for less than one-quarter of U.S. usable iron ore output in 2005. Nearly all of Michigan's output was pellet production. The Empire Mine produced 4.9 Mt of standard and flux pellets, and the Tilden Mine produced 8.0 Mt of magnetite and hematite flux pellets (Koch, 2006, p. 5, 8).

Wisconsin Electric Power Company, which supplies energy to the Empire and Tilden operations, unilaterally changed its method of billing energy charges. Cliffs disputed the change in billing methodology and submitted the matter to the American Arbitration Association. Cliffs placed funds covering what it considered excess charges into an escrow account until the arbitration was complete (Cleveland-Cliffs Inc, 2006a§).

Minnesota.—Minnesota produced more than three-quarters of the usable iron ore in the United States in 2005; nearly all of the output was pellet production. All production from the State came from open pits on the Mesabi Iron Range. Minnesota pellet production, grouped by operating company, is summarized as follows: (a) Hibbing Taconite Company produced 8.6 Mt of pellets; (b) Northshore Mining Company produced 5.0 Mt of standard pellets; (c) United Taconite Company, LLC [owned by Cliffs (70%) and China's Laiwu Steel Group (30%)] produced 5.0 Mt of pellets; (d) Mittal Steel USA produced 2.8 Mt—99% was flux pellets, and 1%, pellet chips; and (e) U.S. Steel produced 5.4 Mt of pellets from its Keewatin Taconite operations and 15.3 Mt of pellets from its Minntac operations (Koch, 2006, p. 9-20; Cleveland-Cliffs Inc, 2006b§).

Keewatin Taconite began construction of facilities to allow for the use of coal and petroleum coke as an alternative fuel to its current natural gas system and to add a wet scrubber system at its taconite pelletizing plant. The alternative fuel system was designed to offset high natural gas prices, while the scrubber was to remove dust from air emissions. These systems became operational early in 2006 and had an original combined cost estimate of $38 million (Scipioni, 2005, 2006).

The Mesabi Nugget Project, which involves the construction of an iron nugget plant at the site of the former LTV Steel Mining Co. property at Hoyt Lakes, MN, was on schedule. The Mesabi Nugget plant was designed to produce 500,000 t/yr of high-quality, 95% to 96% iron-containing pellets from Mesabi taconite ores. Concentrate feed for the plant would initially come from Cliffs' Northshore Mine near Babbitt. Iron Range lawmakers, the Governor's office, and Minnesota Pollution Control Agency officials were expediting the permitting process for the Mesabi Nugget plant (Mesabi Daily News, 2005§).

Cliffs planned to obtain a 23% share of the Mesabi Nugget project by investing $50 million in the project; the investment was approved by Cliffs in the second week of 2006 and included $21 million for the construction and operation of the plant to produce high-quality iron nuggets, $25 million to expand iron ore concentrate production at the Northshore Mine, and $4 million to construct rail facilities that would allow concentrate to be transport to the nugget plant from the Northshore Mine (Mining Engineering, 2006).

PolyMet Mining Corp. closed on the sale of idle iron ore concentrating and auxiliary facilities at Hoyt Lakes. Cliffs acquired the facilities as part of the bankruptcy settlement from the former LTV Steel. Cliffs was expected to receive $3.4 million in cash and 6.2 million common shares of Polymet stock from the sale of the former LTV Steel plant (PolyMet Mining Corp., 2005a, b; Cleveland-Cliffs Inc, 2005a§).

Other States.—Strong demand for iron ore spurred interest in iron ore projects in other States. Palladon Ventures Ltd. completed a preliminary scoping study on the Comstock/

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Mountain Lion Iron Project in Iron County, UT. An update of existing feasibility studies to provide current costs was performed. The study evaluated 10 scenarios for development and concluded that the property value exceeded the $10 million purchase consideration (Palladon Ventures Ltd., 2005c§). Palladon completed the purchase of an idled mine from Geneva Steel Company, and posted a $1.3 million reclamation bond for the property. Palladon began bulk sampling the exposed ore benches to determine the most effective method of beneficiation and to use in negotiations with potential customers. Palladon announced a contract to sell 1.0 Mt of direct shipping ore to a Chinese purchaser, beginning in September, but by yearend, this iron ore had not yet been shipped (Palladon Ventures Ltd., 2005a§, b§).

Tennessee Minerals, LLC announced that 15 Mt of calcined iron ore fines grading greater than 65% iron would be available from its stockpile at Copperhill, TN. Tennessee Minerals rehabilitated a 43-mile [69-kilometer (km)] rail line to provide access to the 53-acre (21-hectare) site and shipped eight trainloads of calcine to Newport News, VA, for eventual transport to China (Tennessee Minerals, LLC, 2005§; Southeast Industrial Development Association, 2006§).

Consumption

U.S. iron ore consumption fell by 7% to 60.1 Mt from a 2004 figure of 64.5 Mt (table 1). Pig iron production at 37.2 Mt was 16% below the 10-year average of 44.4 Mt/yr for 1996 through 2005. Raw steel production using BOF technology fell to 43 Mt—the lowest production level in more than 10 years and 15% below the average production for the past decade.

Consumption of iron ore, including agglomerates, reported to the AISI by integrated producers of iron and steel totaled 58.9 Mt, including 50 Mt of pellets; 8 Mt of sinter, briquettes, and other products; and 0.5 Mt of natural coarse ore (table 6). Of the ore consumed, 78% was domestic; 13%, from Canada; 7%, from Brazil; and 2%, from other countries. Other iron-bearing materials charged to blast furnaces included mill scale, slag scrap, and steel furnace slag.

The three consumption numbers used in this annual review are reported in tables 1, 6, and 7. The first consumption number (60.1 Mt in 2005), in table 1, is the sum of the ore consumed by input type reported by the AISI, the ore consumed in DRI production, and the ore consumed in nonsteel uses, as reported to the USGS (American Iron and Steel Institute, 2006, p. 81). The second consumption number (58.9 Mt in 2005), in table 6, is the ore consumed in U.S. iron and steel plants by type of ore reported by the AISI. The third consumption number is no longer being reported, but previous years are listed in table 7. This consumption figure was the ore consumed in U.S. iron and steel plants by ore type, as reported by the AISI, plus the ore consumed in DRI production (0.33 Mt in 2005) and nonsteel uses (0.93 Mt in 2005). Data on iron ore consumption in nonsteel end uses (table 7) were compiled from USGS surveys.

Price

By the end of February, indications were that world prices for iron ore would increase significantly in the contract year (April 1, 2005, through March 31, 2006). Several price agreements had already been reached between leading iron ore exporters and major steelmakers that contained price increases greater than 70%. Companhia Vale do Rio Doce (CVRD) first negotiated significant price increases with their Asian customers and then signed similar contracts with Arcelor Group in Europe whereby deliveries for the contract year for Carajás and Southern System iron ore fines, free on board (f.o.b.) their respective ports, were increased by 71.5% relative to those of 2004 (Samor and Glader, 2005; Companhia Vale do Rio Doce, 2005§). Rio Tinto plc subsequently concluded its negotiations with Nippon Steel Corporation for the contract year. The price for lump ore, fine ore, and Yandi ore were all increased by 71.5% on a cents per dry metric ton unit basis (Rio Tinto plc, 2005§). Other major steelmakers quickly, but reluctantly, signed similar agreements that contained significant price increases with CVRD and Rio Tinto, while BHP Billiton Limited (BHPB) requested yet higher increases than either Rio Tinto or CVRD (Bell, 2005§).

BHPB held out for several weeks for a $7.50 to $10 per ton rate premium, but finally settled annual contracts for iron ore at the same rate as both CVRD and Rio Tinto. Resistance from the China Iron & Steel Association, formed in mid-2003 by Chinese steel producers, helped hold BHPB prices to the Japanese and European established benchmark levels (Jones, 2005b; Mining Journal, 2005a).

Iron ore contract price increases, on a percentage basis, were similar in the European and Asian markets. In spite of iron ore prices having declined in real terms through 2002, the price of Carajás fines, an ore grade produced by CVRD and sold to Europe, when denominated in U.S. dollars, reached 65.00 cents per 1% iron per ton, a 71.5% increase compared with the previous contract year, which had been the highest price in the past 9 years (United Nations Conference on Trade and Development, 2006, p. 84).

U.S. prices as indicated by Cliffs also increased relative to 2004 realized prices. The estimated effect of international pellet pricing was anticipated to increase revenues by almost 18% per ton (table 15). An additional $1.56 per ton would be realized based on known contractual base pricing, lag year adjustments, and capped pricing, while the effect of additional price adjustment factors was not fully known (Cleveland-Cliffs Inc, 2005b§).

According to CRU International Ltd., lower prices for iron ore exported from India to China were linked to a reduction in Chinese steel prices. Although a slight reduction in growth was seen, Chinese steel production increased by 41% compared with that of the past year (CRU Monitor, 2005).

The rise in Chinese imports in 2005, continued tight supply, and increased world spot prices for iron ore (almost 50% higher per ton than the price in 2005-06 annual contracts) suggested that benchmark iron ore prices would rise again in 2006. Counterbalancing these upward market forces were short-term overcapacity in Chinese steelmaking and falling Chinese steel product prices. An additional factor in the pricing mix was BHPB's continued interest in having iron ore prices reflect

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a transport premium for the cost to the purchaser of iron ore delivered at the steel plant. In spite of steelmakers having started to reduce the price of their products to recover sales volume, one major iron ore company pushed for a 40% increase in prices. By October, preliminary negotiations of iron ore prices had begun at a steel seminar held in Qingdao, China (Clarke, 2005a; China Press, 2005§; Tan, 2005§; Wilson, 2005§).

Transportation

Shipments of iron ore on the Great Lakes dropped by 7% in 2005 compared with those of 2004 and 4% compared with the average of shipments for the previous 5 years. Total dry-bulk shipments in 2005 on the Great Lakes were down by more than 12% compared with the average for the same 5-year period (Lake Carriers' Association, 2006).

The Soo locks officially closed to vessel traffic at midnight on January 15 and reopened on March 25; ocean traffic on the St. Lawrence Seaway recommenced for the 2005 season on March 23 for the Welland Canal section and on March 25 for the Montreal-Lake Ontario section; and the last ocean-going vessel left the Port of Duluth on December 19 in time for the closing of the Welland Canal and Montreal-Lake Ontario locks before yearend (Duluth Seaway Port Authority, 2005§). A milestone was reached as the Soo locks at Sault Ste. Marie, MI, celebrated its 150th anniversary. The first lock on the St. Mary's River was completed in 1855 by Fairbanks Scale Company (Flesher, 2005§).

The Port of New Orleans, a major iron ore importing port, sustained considerable damage from hurricane Katrina. Six wharves were heavily damaged, six were moderately damaged, and eight were in working order after electricity and power became available (Burgert, 2005).

Foreign Trade

U.S. net imports of iron ore in 2005 were 1.2 Mt, which represented 2.0% of domestic consumption. Exports increased by 40%, while imports increased by 11% compared with 2004 figures. Nearly all U.S. iron ore exports (11.6 Mt) were pellets, and 95% of the exports were shipped via the Great Lakes to Canadian steel companies, while 2% was shipped to each of China and Slovakia. U.S. imports totaled 13.0 Mt, of which Brazil's share decreased to 32%; Canada's share increased to 58% (tables 1, 8-14).

World Industry Structure

Consumption.—Although global iron ore consumption is not measured directly, there are indicators that show whether it rose or fell—imports of iron ore and production of crude steel, DRI, and pig iron. DRI and pig iron production tend to be more direct indicators of iron ore consumption than crude steel production because part of steel production comes from scrap-consuming minimills. Iron ore imports are not a straightforward indicator of a change in iron ore consumption in any country that produces iron ore unless the country's ore production remains static. Estimates of world consumption of iron ore increased as the result of a 9% increase in pig iron production compared with 2004 levels. Of the six countries that had 4% or more of world pig iron production from 1996 through 2005, only the United States had negative growth in pig iron production over this period. All others had increases over this period, as follows: China, 207%; Brazil, 41%; Russia, 31%; Japan, 11%; and Germany, 4%. Of the five countries that had 4% or more of world pig iron production in 2005, three showed a decrease in production—the United States, 14%; Russia, 4%; and Brazil, 2%. Japan's production had a very slight increase, while China increased production of pig iron by 28%.

World crude steel production surpassed 1.1 billion metric tons (Gt) and rose by 7% from 2004 to 2005. Four countries accounted for 5% or more of world production in 2005. Of those countries, China produced almost 77 Mt more crude steel in 2005 than in 2004. The others (Japan, Russia, and the United States) combined produced 6 Mt more crude steel in 2004 than in 2005. The world crude steel production, excluding China, decreased by more than 5.7 Mt. The four previously listed countries along with Germany and the Republic of Korea accounted for almost 59% of combined world crude steel production for 1996 through 2005. China's production rose by 245% during that period, while that of the United States fell by 2% (United Nations Conference on Trade and Development, 2006, p. 92-96).

Demand.—Continued strong iron ore demand has led to increased interest in mine development. This increased demand continued to be driven by Chinese economic growth. In spite of new iron ore production capacity, world supply of iron ore was expected to remain tight through 2006, partially owing to increased steel exports by China. World DRI production rose to 56.1 Mt, which was 3% more than that of 2004 (Midrex Technologies, Inc., 2006§).

Production.—World iron ore production of 1.53 Gt, gross weight, surpassed 2004 production by 13%. World production has been more than 1 Gt, gross weight, since it first exceeded that level in 1995. Australia's and Brazil's combined share of world production from 2001 through 2005 averaged 36%. In 2005, iron ore was produced in 45 countries, with production exceeding 1 Mt, gross weight, in 25 of those countries.

Australian miners Rio Tinto Limited and BHPB announced plans to invest an additional $1.35 billion and $1.3 billion, respectively, in iron ore projects. Brazil's CVRD followed suit with an announcement to invest a further $759 million to expand its Itiberitos operations (Mining Journal, 2005d).

Trade.—World iron ore imports of 713 Mt rose by 9% compared with 2004 levels. Following large year-on-year increases in imports for the past 5 years (27% in 2000, 32% in 2001, 21% in 2002, 33% in 2003, and 40% in 2004), China posted another sharp rise to 275 Mt in 2005 from 208 Mt in 2004—a gain of more than 32%. Since 2001, four countries have accounted for more than 60% of world iron ore imports. Germany's share of imports in that period fell to 5% from 8%, Japan's share fell to 19% from 26%, and the Republic of Korea's share fell to 6% from 9%. China's share rose during this 5-year period to 39% from 19%.

Australia's and Brazil's combined share of world iron ore exports fell slightly to 65% in 2005 from 66% in 2004. Five countries represented more than 80% of world iron ore exports. In decreasing order of market share, Australia held 33%; Brazil, 31%; India, 11%; Canada, 4%; and South Africa, 4% (United

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Nations Conference on Trade and Development, 2006, p. 76-79).

World Review

Australia.—BHPB's share of total world mine production was 97.5 Mt, a 9% increase from that of 2004. BHPB's share of saleable quantities of iron ore (wet) from its mines was as follows: Yandi JV (85% owned), 34.4 Mt; Mt. Newman JV (85% owned), 25.4 Mt; Area C Joint Venture (JV) (85% owned), 18.5 Mt; Samarco, Brazil, (50% owned), 7.5 Mt; Jimblebar, 6.0 Mt; and Goldsworthy JV (85% owned), 5.7 Mt (BHP Billiton Limited, 2006§).

Rio Tinto Limited's share of total world mine production was 124.5 Mt, a 15% increase from that of 2004. Rio Tinto's share of saleable quantities of iron ore plus pellets from its mines was as follows: Hamersley, 74.4 Mt; Robe River (53% owned), 27.8 Mt; Iron Ore Company of Canada (59% owned), 9.2 Mt; Eastern Range, 6.6 Mt; Channar (60% owned), 5.2 Mt; and Corumba, Brazil, 1.4 Mt (Rio Tinto plc, 2006§).

At yearend, Grange Resources Limited was finalizing a bankable feasibility study on its Southdown Project in Western Australia. This magnetite iron ore project, located approximately 90 km northeast of Albany, envisioned ore shipments from the Port of Albany to a yet-to-be-constructed pelletizing plant at Kemaman in Malaysia. A scoping study indicated operating costs in the range of US$32 per ton f.o.b. pelletizing plant and project costs for the mine and pelletizing plant of about US$640 million. Recent resource estimates indicated an increase to 458 Mt grading 37% magnetite. A draft environmental scoping study was submitted by Grange in November (MineBox, 2005b§; Grange Resources Limited, 2006§).

Cliffs gained control of Portman Limited, the third ranked iron ore producer in Australia. Portman operated two iron ore mines—the Koolyanobbing Mine near Southern Cross in Western Australia and the Cockatoo Island Mine off the northern coast of Western Australia, of which it had a 50% ownership (Cleveland-Cliffs Inc, 2005c§; Portman Limited, 2005§). Reed Resources Ltd. signed a joint-venture agreement with Portman for drilling on the Mt. Finnerty iron ore deposit, 65 km east of Portman's Koolyanobbing operations. By signing the agreement, Portman would earn 80% ownership of the project if it spent $A300,000 over the following 3 years to determine the project's ore reserves (Metal Bulletin, 2005c).

Ivanhoe Mines Ltd. (Singapore) announced the sale of its Savage River Mine—a complex consisting of iron ore mining, pelletizing, and shipping facilities in Tasmania. The purchaser, Stemcor Holdings Limited (United Kingdom), agreed to pay Ivanhoe US$21.5 million plus annual payments for the next 5 years based on a formula related to the Nibrasco/Japan Steel Mills pellet price for the 1.8 Mt/yr sales of pellets (Ivanhoe Mines Ltd., 2005§).

In early 2005, China Metallurgical Construction Group (CMCG) announced that it was not prepared to finance Fortescue Metals Group's (FMG) Christmas Creek iron ore project, a part of the Pilbara iron ore joint-venture project, in Western Australia. FMG claimed that CMCG was now requiring an equity interest to become involved in the financing. Subsequent to CMCG's decision, FMG requested Citigroup to open negotiations through a tender for the Pilbara iron ore joint-venture project (Clarke, 2005b; Mining Journal, 2005b).

FMG upgraded its resource estimates, with 77% conversion to reserve category under the Joint Ore Reserves Committee (JORC) classification system, to probable ore reserves of 619 Mt at Christmas Creek and 447 Mt at Cloud Break in the Pilbara's Chichester Ranges. These probable ore reserves were further segregated to 359 Mt of high-grade ore with an average grade of 60.4% and 707 Mt of lower-grade ore with an average grade of 57.7%. Additional infill drilling was planned to further upgrade the reserve estimates (Fortescue Metals Group Ltd, 2005§).

Kumba Resources Limited sold its share of the Hope Downs project to Hancock Prospecting Pty Ltd. Hancock purchased Kumba's 50% share of the project for $A231.4 million with a discount for early payment. Subsequently, Hancock announced that Rio Tinto would take a 50% stake in and manage the $A2 billion project. Rio Tinto's participation in the project drastically reduced rail requirements. An initial 30-km spur was proposed to connect the planned 25- to 30-Mt/yr mine to existing infrastructure and allow access to Hope Down's 1 Gt of high-grade iron ore reserves (Kumba Resources Limited, 2005§; Phaceas, 2005§).

Mount Gibson Iron Limited agreed with Shougang Holding (Hong Kong) Limited to develop the Extension Hill magnetite deposit in the Mid West region of Western Australia. A feasibility study for the 5-Mt/yr mine, concentrator, slurry pipeline, and associated port infrastructure was to be completed early in 2006. If the study was positive, Asia Iron Holdings Limited (a 63%-owned subsidiary of Mount Gibson) would allocate $A15 million towards development of Extension Hill. Shougang would provide $A120 million in equity to earn a 50% interest in the newly formed Extension Hill Pty Ltd (Mount Gibson Iron Limited, 2005§). The Extension Hill project was expected to cost $A750 million, including a $A340 million, 270-km iron ore slurry pipeline to the Port of Geraldton and two pellet plants to be built at Longtan (near Nanjing) in China (Metal Bulletin, 2005b).

BHPB approved the Rapid Growth Project 3 (RGP3) to increase capacity by 20 Mt/yr to 42 Mt/yr at the Area C iron ore operations. BHPB's board approved the $1.3 billion investment for an 85% share in the project. RGP3 includes development of a new pit, new mine crushing and screening facilities, increased port and rail facilities, and sustaining capital to upgrade aging port and rail infrastructure. The current Rapid Growth Project 2 (RGP2) is on schedule and initial production was planned for the second half of 2006. New RGP3 work began immediately with initial production planned for the fourth quarter of 2007 (BHP Billiton Limited, 2005§).

Bolivia.—Bolivia planned to submit the El Mutún iron ore deposit near Puerto Suarez to international auction in March. The site, close to the Brazilian border, has proven reserves of 175 Mt averaging 67% iron content and an estimated reserve of 40 Gt of primary ore (Kinch, 2005). The bidding process, already behind schedule, was further delayed by the election of a new President at the end of 2005. The bids were to be delayed a further 60 days from the earlier December 21 deadline following statements by the President-elect that the property would be nationalized, if the bidding process was not postponed for the 2-month period. Five companies bought bidding rules—Brazil's EBX Group, China's Luneng Shandong Group, European steel giant Mittal Steel, Argentina's Siderar Sociedad Anonima Industrial y Comercial, and India's Jindal Steel and

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Power Limited (Beltrán, 2005§).

Brazil.—CVRD announced 2005 production based on consolidated Brazilian generally accepted accounting practices (BGAAP). Consolidated BGAAP production figures include the total production of all the companies in which CVRD had more than 50% of the voting capital and effective control with production proportional to CVRD's stake in the companies and exclude production volumes of companies in which CVRD had minority interests. CVRD's total iron ore production increased by 10.3% from 2004 to 2005, and CVRD's share of salable quantities of iron ore was as follows: Southern System, 109.9 Mt; Carajás, 72.5 Mt; Caemi, 50.4 Mt; Samarco, 6.6 Mt; and Urucum, 1.1 Mt. CVRD's 2005 pellet production was 36.4 Mt, an increase of 3.0% from that of 2004, and the breakdown of salable quantities of iron ore pellets was as follows: Samarco, 6.9 Mt; São Luís, 6.2 Mt; CVRD I and II, 5.9 Mt; Fábrica, 4.3 Mt; Nibrasco, 4.6 Mt; Kobrasco, 2.4 Mt; Hispanobras, 2.1 Mt; and others, 4.0 Mt (Companhia Vale do Rio Doce, 2006§).

Improved performance by CVRD in 2005 was for the most part the result of new projects—Fábrica Nova, Carajás expansion, and Capão Xavier—and in spite of a maintenance stoppage at the São Luís pellet plant during the first part of the year. The Fábrica Nova Mine, which began operations in the second quarter of 2005, produced 7.8 Mt, and Capão Xavier produced 11.3 Mt, 7.1 Mt more than in 2004. The Capão Xavier Mine started operations in July 2004, so 2005 was its first year of operation at full capacity (Companhia Vale do Rio Doce, 2006§).

Companhia Siderúrgica Nacional (CSN) signed a contract with CVRD to supply 54.7 Mt of iron ore over the next 10¼ years from the Casa de Pedra Mine. The contract, worth US$2 billion, gave CSN the incentive to spend an additional US$520 million to expand the mine capacity to 40 Mt/yr from 15 Mt/yr and to make the necessary additions to port facilities at Septiba (Mining Journal, 2005c; Smith, 2005§).

Brazil's Administrative Council for Economic Defense (CADE) approved CVRD's acquisitions of five iron ore producers—Belém–Administrações e Participações Ltda., Caemi Mineração e Metalurgica S.A., Ferteco Mineração S.A., Mineração Socoimex Ltda., and Samitri S.A. After 5 years of investigation, CADE placed an important caveat on maintaining the acquisition of Ferteco—CVRD must relinquish its right of first refusal on CSN's surplus iron ore produced at the Casa de Pedra Mine (Metal Bulletin, 2005a).

Canada.—Québec Cartier Mining Company (QCM) (a Canadian iron ore and pellet producer partially-owned by Dofasco Inc.) settled a 6-week strike after having an initial contract offer rejected by the United Steelworkers union. Union members accepted a 6-year contract following prolonged negotiations. Later that year, Dofasco completed the acquisition of QCM by purchasing all preferred shares held by Caemi and Investissment Québec (Dofasco Inc., 2005§, Koch, 2006, p. 14-15).

In November, Arcelor S.A. (Luxembourg) launched an unsolicited bid worth US$3.7 billion to obtain majority ownership of Dofasco, which owned 28.6% of Wabush Mines and 100% of QCM (Markham and others, 2005). Germany's ThyssenKrupp AG raised its takeover bid for Dofasco to Can$4.9 billion in an effort to match the hostile bid from Arcelor. Dofasco's board preferred the takeover offer from ThyssenKrupp because the German steelmaker planned to maintain the Dofasco name and management; place all North American operations, including a stainless steel mill in Mexico, under Dofasco control; and continue some form of profit-sharing for the largely nonunion workforce (Austen, 2006§).

Chile.—Admiralty Resources NL (Australia) purchased a 50% interest in Compañía Minera Santa Barbara, which had nine properties with inferred iron ore mineral resources totaling 41 Mt. In December, a measured and probable ore reserve of 32.5 Mt at an average grade of 12.2%, equivalent to 6 Mt at an ore grade of 60% iron, was established for the first of these properties—the Japonesa Mine (Admiralty Resources NL, 2005§; MineBox, 2005a§).

Chile's Compañía Minera del Pacífico S.A. (CMP) (a subsidiary of Compañía de Aceros del Pacífico) planned to spend US$160 million to expand its exports. CMP produced 7 Mt/yr of pellets and iron ore and was in the final stages of approval for a 3-Mt/yr pellet plant to process magnetite-rich tailings from Phelps Dodge Corporation's Candelaria copper mine (Harris, 2005).

China.—China announced plans to institute an iron ore import license system in 2005. The new system appeared to be designed to curb speculative trading of iron ore, reduce market access to smaller, less efficient steel producers, and better organize the country's shipping requirements (Australian Investment Review, 2005§).

According to China Daily, two Chinese companies and the State Development & Investment Corporation signed a joint venture agreement to build a 50-Mt/yr coal terminal. The 36-meter-deep terminal, to be located at Caofeidian in Heibei Province, would also handle iron ore and crude oil (McCloskey's Coal News, 2005§). China's Qingdao Port in Shandong Province handled more than 24 Mt of iron ore imports in the first half of 2005. In 2004, Quindao surpassed Rotterdam (Netherlands) as the world's leading importer of iron ore (Yahoo! Asia News, 2005§).

India.—India introduced a dual rail freight policy for iron ore. Companies transporting iron ore by rail to ports for export were charged double the rate for iron ore being transported to domestic blast furnace operations (Hindu Business Line, The, 2005§).

Companies from Australia and the Republic of Korea and Chinese government entities were all actively pursuing mine development opportunities in India. In 1995, Rio Tinto entered into a joint-venture agreement with Orissa Mining Corporation to develop two mines—Gandhamardan and Malangtuli—with much of the ore planned for export. In 2005, after 40 companies expressed interest in developing steel plants in Orissa State, the Government of India decided to renegotiate the original Orissa Mining joint venture. POSCO, in association with BHPB, proposed developing a steel plant near Paradip along with mining and support infrastructure. A Chinese delegation met with the Orissa Mining and government representatives from the States of Jharkhand and Karnataka to discuss raw material sourcing, as well as mining and steelmaking opportunities within India (Saha, 2005§; Telegraph (Calcutta), The, 2005§).

Kudremukh Iron Ore Company Limited (KIOCL) (a Government-owned enterprise and one of the world's 15 leading iron ore miners) ceased mining at its Kudremukh leasehold. KIOCL, which exported 100% of its iron ore, was first granted a mining lease in the Western Ghats area of Karnataka State in 1969. In 1987, the mine was designated part of the Kudremukh National Forest, and in 2002, KIOCL was informed that mine

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production would have to stop by 2005 (Rosenquist, 2006).

Indonesia.—Aretae Ltd. (Singapore) received one mining license and was expecting to get a another for two deposits that have estimated reserves of between 10 and 12 Mt of iron ore with 63.5% to 68% iron content (Metal Bulletin Daily, 2005). PT Krakatau Steel signed a memorandum of understanding with Chinese investors to develop a US$1 billion iron ore project in Kalimantan Province. The mine was to produce 2.5 Mt/yr of iron ore, with plant construction beginning in early 2006 (Indonesia Investment Coordinating Board, 2005§).

Korea, North.—Reports indicated that China would invest US$480 million to explore North Korea's Musan iron ore deposit. Musan had resources of 7 Gt, with some ore containing 66% iron. Plans were to develop reserves sufficient to support a 7-Mt/yr steel plant. In November, Tonghua Iron & Steel (Group) Co. Ltd. (a mid-sized state-owned steelmaker based in Tonghua City, Jilin Province, in northeastern China) expected to sign a US$867 million, 50-year exploration-rights deal with the Musan iron ore mine (Skillings Mining Review, 2005a; Asia Times Online, 2005§).

Liberia.—In December 2004, Rio Tinto and Mittal Steel submitted expressions of interest in the western Liberia. Liminco (a Liberian state entity) held the concession for unexploited deposits at Buluton, Mount Beeton, Mount Bele, Mount Mlenton, and Tokadeh (Jones, 2005a). Mittal Steel subsequently entered into a mining development agreement with the Government of Liberia for access to 1 Gt of iron ore reserves in the western part of the country. Initial cost estimates for development of mines and rail, community, and port infrastructure were approximately $900 million (Mittal Steel Corporation, 2005§).

Philippines.—In Camarines Norte, a US$20 million mine site project to pulverize iron ore into iron sands for shipment to China was expected to be completed in April (Kirk, 2005).

Russia.—Fears that exports of Russian and Kazakh iron ore to Chinese steelmakers would impact supplies prompted Russia's Magnitogorsk Iron & Steel Works Open Joint Stock Company (MMK) to consider expanding its captive iron ore mines to increase production from the 10% of supply now provided. Metal Bulletin reported that MMK was proceeding with two strategies to increase iron ore shipments. The first was to acquire an existing mine—with the Sokolovsko-Sarbaisky Mine only 300 km from the steel plant a strong candidate. The second was to explore for and develop iron ore deposits in Chelyabinsk Oblast and other regions (Rivituso, 2005).

South Africa.—Kumba Resources approved the 10-Mt/yr Sishen Expansion Project, which would expand production to 38 Mt/yr from 28 Mt/yr by 2009 at the Sishen iron ore mine in Northern Cape Province. The expansion decision followed agreement with the government-run Transnet to expand rail and port capacity and revise rail tariffs to a rand base rather than a U.S. dollar base (Mining Journal, 2005e).

A second ship loader became operational at the Saldhana Port in March, boosting the port's export capacity to 32 Mt/yr. A second rail car tippler, although expected to be available later in 2005 would not come online until 2006. Saldanha's tippling capacity could reach 50 Mt/yr within 6 months of commissioning of the new tipple (Metal Bulletin, 2005d; Freight & Trading Weekly, 2006§).

Sweden.—Luossavaara-Kiirunavaara Aktiebolag (LKAB) increased pellet production to 16.5 Mt from 16.0 Mt in 2004 and increased production of fines to 6.8 Mt from 6.2 Mt in 2004. LKAB planned to invest US$762 million, the largest investment in the company's 115-year history, to build a sixth pelletizing plant. The investment would not only include the pelletizing plant, but also a concentrator, haulage and terminal facilities, and several environmental upgrade projects. The new plants, to be built adjacent to existing plants at Kiruna, were expected to provide an additional 120 permanent jobs, have a capacity of 5 Mt/yr of pellets, and be operational in early 2008. With this expansion, Kiruna would produce pellets exclusively, while Malmberget operations would remain capable of producing iron ore fines (Luossavaara-Kiirunavaara Aktiebolag, 2006, p. 37; 2005§).

Ukraine.—Mittal Steel, the world's leading steel producer, acquired a 93% stake in Ukraine-based steel producer Kryvorizhstal Mining and Metallurgy Kombinat JSC for about US$4.8 billion. In an annulled privatization agreement, KryvorishStal had been purchased in 2004 by Investment Metallurgical Union at one-sixth the price later paid by Mittal. In 2004, KryvorizhStal produced 7.0 Mt of crude steel, 6.0 Mt of rolled steel products, and 15.5 Mt of iron ore (Mining Journal, 2005f; Ritchie, 2005b).

The purchase of KryvorizhStal was just one step in Mittal's overall goal of becoming more than 80% self-sufficient in iron ore by 2010. It was anticipated that Mittal would add more than 28 Mt/yr of iron ore production capacity upon completion of all current projects (Ritchie, 2005a).

Current Research and Technology

Rio Tinto Limited announced the hot commissioning at the HIsmelt Kwinana Joint Venture plant in Western Australia. HIsmelt, a new technology developed by Rio Tinto, enables direct smelting of fine iron ore and coal into molten iron. Without coke ovens, sinter plants, or pelletizing plants, it claims to offer significant operational and environmental advantages over existing iron-making techniques. It is flexible in terms of the qualities of iron ore—including high phosphorus ores—and coal (noncoking) that it uses to produce premium quality iron. The plant moved into a rampup phase and was expected to reach full production of 0.8 Mt/yr during the next 3 years. The iron produced will be sold as pig iron (Rio Tinto Limited, 2005§).

Outlook

Minnesota legislative changes are expected to dramatically affect the structure of the U.S. iron industry in coming years with a conversion of ore to DRI and then to steel products—all within the State of Minnesota. The Nashwauk steel project is tentatively scheduled for slab caster plant commissioning as early as 2009, while the Mesabi Nugget project is expected to begin commercial production in 2008.

It appears that U.S. production in 2006 is on track to remain about the same as that of 2005. Most U.S. iron ore production is sold directly to the domestic steel industry, although some domestic ore is shipped to Canada, while other ore is traded for Canadian ore subsequently shipped to China. This domestic

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dependence is not expected to change in the near future.

Information about steel industry trends is provided in the "Outlook" section in the Iron and Steel chapter of the 2005 USGS Minerals Yearbook, Volume I, Metals and Minerals. Growth of the U.S. iron ore industry within the next few years will be tied to the growth of the integrated steelworks along the Great Lakes and development of direct reduction processes planned for northern Minnesota, although some deposits are also being considered as a source of export concentrate.

The growth of DRI would allow the iron ore industry to supply the expanding minimill sector of the U.S. steel industry. Imported DRI already plays an important role for coastal U.S. steel producers since steel alloy purities can not be readily achieved with scrap. Domestically produced DRI could become competitive further inland where cheaper power is available. Even in the event of strong global DRI growth during the next decade, DRI can replace only a small portion of the world's blast furnace production. The blast furnace is expected to remain the mainstay of the iron and steel industry during the midterm.

International imports of iron ore and production of iron ore and pig iron—three key indicators of iron ore consumption—indicate that the international iron ore industry will continue to be dependent on growing Chinese iron ore consumption. Increased participation by China in overseas joint ventures, robust imports of iron ore, and continued high levels of domestic production of low-grade ores in China imply that iron ore consumption will remain strong, although a larger portion of the supply is expected to be satisfied by iron ore from China's equity portion of joint ventures.

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TABLE 1
SALIENT IRON ORE STATISTICS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

	2001	2002	2003	2004	2005
United States, iron ore, usable, less than 5% manganese:[2]					
Production	46,200	51,600	48,600	54,700	54,300
Shipments:					
Quantity	50,600	51,500	46,100	54,900	53,200
Value[e]	1,210,000	1,340,000	1,490,000	2,080,000	2,370,000
Average value at mines dollars per metric ton	23.87	26.04	32.30	37.92	44.50
Exports:					
Quantity	5,610	6,750	6,770	8,400	11,800
Value	229,000	249,000	248,000	334,000	584,000
Imports for consumption:					
Quantity	10,700	12,500	12,600	11,800	13,000
Value	293,000	313,000	328,000	371,000	532,000
Consumption, iron ore and agglomerates	65,700	59,700	61,600	64,500	60,100
Stocks, December 31:					
At mines, plants and loading docks[3]	3,800	4,090	4,910	3,930	2,870 [4]
At receiving docks[5]	1,960	1,820	1,630	(6)	(6)
At consuming plants	12,300	12,400	10,900	(6)	(6)
Total[7]	18,000	18,300	17,500	(6)	(6)
Additional stocks, December 31:					
Crude ore at mines and plants	NA	NA	NA	NA	1,170 [4]
Unagglomerated concentrates for pelletizing plants	NA	NA	NA	NA	1,870
World, production[8]	1,050,000 [r]	1,100,000 [r]	1,220,000 [r]	1,360,000 [r]	1,530,000 [e]

[e]Estimated. [r]Revised. NA Not available.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Direct-shipping ore, concentrates, agglomerates, and byproduct ore.

[3]Excludes byproduct ore.

[4]Crude ore stocks and unagglomerated concentrates for pelletizing plants removed. Marketable stocks only.

[5]Transfer and/or receiving docks of lower Great Lake ports.

[6]American Iron and Steel Institute no longer collects this data as of 2004.

[7]Sum of stocks at mines, consuming plants, and U.S. docks.

[8]Gross weight.

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TABLE 2

EMPLOYMENT AT IRON ORE MINES AND BENEFICIATING PLANTS, QUANTITY AND TENOR OF ORE PRODUCED, AND AVERAGE OUTPUT PER WORKER HOUR IN THE UNITED STATES IN 2005, BY DISTRICT AND STATE[1]

			Production						
							Average quantity per worker hour (metric tons)		
District and State	Average number of employees	Worker hours (thousands)	Crude ore (thousand metric tons)	Usable ore (thousand metric tons)	Iron contained (in usable ore) (thousand metric tons)	Iron content natural (percent)	Crude ore	Usable ore	Iron contained
Lake Superior:									
Michigan[2]	1,160	2,570	37,900	12,900	7,790	60.2	14.79	5.04	3.04
Minnesota	3,170	6,540	138,000	41,400	26,400	63.8	21.07	6.33	4.04
Total or average	4,330	9,100	176,000	54,300	34,200	63.0	19.30	5.97	3.76
Other States[3]	19	38	9	9	5	54.0	0.25	0.25	0.13
Grand total or average	4,450	9,140	176,000	54,300	34,200	63.0	19.22	5.94	3.74

[1]Data are rounded to no more than three significant digits, except "Average per worker hour, crude ore" and "Average per worker hour, usable ore;" may not add to totals shown.

[2]Does not include professional or clerical workers at mines, pelletizing plants, maintenance shops, or research lab workers.

[3]Includes California and South Dakota.

TABLE 3

CRUDE IRON ORE MINED IN THE UNITED STATES IN 2005, BY DISTRICT, STATE, AND MINING METHOD[1, 2]

District and State	Number of mines	Open pit (thousand metric tons)	Underground (thousand metric tons)	Total (thousand metric tons)
Lake Superior:				
Michigan	2	37,900	--	37,900
Minnesota	6	138,000	--	138,000
Total	8	176,000	--	176,000
Other States	4	9	--	9
Grand total	12	176,000	--	176,000

-- Zero.

[1]Includes some byproduct ore. Excludes ore containing 5% or more managanese.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 4
USABLE IRON ORE PRODUCED IN THE UNITED STATES IN 2005,
BY DISTRICT, STATE, AND TYPE OF PRODUCT[1, 2]

(Thousand metric tons)

District and State	Direct shipping ore	Concentrates	Agglomerates[3]	Total
Lake Superior:				
Michigan	30	--	12,900	12,900
Minnesota	--	63	41,300	41,400
Total	30	63	54,200	54,300
Other States[4]	--	9	--	9
Grand total	30	72	54,200	54,300

-- Zero.

[1]Excludes ore containing 5% or more manganese.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Data may include pellet chips, screenings, and sinter.

[4]Includes California and South Dakota.

TABLE 5
SHIPMENTS OF USABLE IRON ORE FROM MINES IN THE UNITED STATES IN 2005[1, 2]

District and State	Gross weight of ore shipped (thousand metric tons)				Average iron content, natural (percent)	Value (thousands)
	Direct shipping ore	Concentrates	Agglomerates	Total		
Lake Superior:						
Michigan	33	--	12,600	12,600	60.2	W
Minnesota	--	63	40,500	40,600	63.8	W
Total reportable or average	33	63	53,100	53,200	63.0	$2,370,000
Other States[3]	--	10	--	10	54.0	368
Grand total or average	33	73	53,100	53,200	63.0	2,370,000 [e]

[e]Estimated. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Includes byproduct ore. Excludes ore containing 5% or more manganese.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Includes California and South Dakota.

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TABLE 6
CONSUMPTION OF IRON ORE AT U.S. IRON AND STEEL PLANTS, BY TYPE OF PRODUCT[1]

(Thousand metric tons)

Type of product	2004	2005
Blast furnaces:		
Direct-shipping ore	26	34
Pellets	55,000	50,100
Sinter[2]	7,900	8,200
Total	62,900	58,300
Steelmaking furnaces:		
Direct-shipping ore	450	431
Sinter[2]	147	113
Total	597	544
Grand total	63,500	58,900

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes briquettes, nodules, and other.

Source: American Iron and Steel Institute.

TABLE 7
U.S. CONSUMPTION OF IRON ORE, BY END USE[1, 2]

(Thousand metric tons)

Year	Blast furnaces[3]	Steel furnaces[3]	Sintering plants[3, 4]	Miscellaneous[3, 5]	Subtotal integrated iron and steel plants[6]	Direct-reduced iron for steelmaking[7]	Nonsteel end uses[8]	Total
2001	57,300	35	4,560	--	61,900	180 r	756	64,400
2002	52,900	301	5,620	1	58,800	705	828	60,300
2003	53,800	133	5,650	--	59,500	315	791	60,600
2004	NA	NA	NA	NA	NA	270	794	NA
2005	NA	NA	NA	NA	NA	330	928	NA

rRevised. NA Not available. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes agglomerates. Excludes ore containing 5% or more manganese.
[3]Data provided by American Iron and Steel Institute.
[4]Excludes dust, mill scale, and other revert iron-bearing materials.
[5]Sold to nonreporting companies or used for purposes not listed.
[6]Data provided by American Iron Ore Association.
[7]U.S. Geological Survey estimates based on production reports compiled by Midrex Corp.
[8]An estimate, which includes iron ore consumed in production of cement and iron ore shipped for use in manufacturing paint, ferrites, heavy media, cattle feed, refractory and weighing materials, and for use in lead smelting.

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TABLE 8

U.S. EXPORTS OF IRON ORE, BY COUNTRY OF DESTINATION[1, 2]

(Thousand metric tons and thousand dollars)

	2004		2005	
Country	Quantity	Value	Quantity	Value
Canada	7,820	311,000	11,200	555,000
China	297	13,600	282	16,500
Slovakia	188	6,130	237	6,630
Other	88	3,640	116	6,090
Total	8,400	334,000	11,800	584,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes agglomerates.

Source: U.S. Census Bureau.

TABLE 9

U.S. EXPORTS OF IRON ORE, BY TYPE OF PRODUCT[1, 2]

	2004			2005		
Type of product	Quantity (thousand metric tons)	Value (thousands)	Unit value[3, 4] (dollars per metric ton)	Quantity (thousand metric tons)	Value (thousands)	Unit value[3, 4] (dollars per metric ton)
Concentrates	24	$695	29.36	89	$3,520	39.55
Coarse ores	8	186	23.89	1	62	114.07
Fine ores	255	8,520	33.36	60	1,980	33.00
Pellets	8,100	325,000	40.06	11,600	578,000	49.70
Briquettes	3	114	41.63	7	352	47.41
Other agglomerates	2	172	75.97	2	144	89.70
Roasted pyrites	1	100	71.55	1	87	58.10
Total	8,400	334,000	39.82	11,800	584,000	49.55

[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.

[2]Includes agglomerates.

[3]Unit values shown are calculated from unrounded data.

[4]Weighted average calculated from unrounded data by dividing total value by total tonnage.

Source: U.S. Census Bureau.

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TABLE 10

U.S. IMPORTS OF IRON ORE, BY COUNTRY AND TYPE OF PRODUCT[1, 2]

Country and type of product	2004 Quantity (thousand metric tons)	2004 Value (thousands)	2004 Unit value[3, 4] (dollars per metric ton)	2005 Quantity (thousand metric tons)	2005 Value (thousands)	2005 Unit value[3, 4] (dollars per metric ton)
Country:						
Australia	(5)	$24	54.15	1	$11	18.00
Bahamas, The	--	--	--	140	4,850	34.70
Brazil	5,020	140,000	27.97	4,180	178,000	42.65
Canada	5,830	190,000	32.53	7,510	299,000	39.88
Chile	244	6,380	26.15	270	10,700	39.56
Finland	76	6,190	81.18	9	383	41.03
Greece	--	--	--	49	963	19.69
Mexico	49	1,220	24.81	41	1,600	39.32
Peru	56	1,030 r	18.58 r	33	1,060	32.48
Russia	--	--	--	99	8,550	86.00
South Africa	104	4,100	39.29	--	--	--
Sweden	111	4,520	40.87	133	6,710	50.42
Trinidad and Tobago	--	--	--	375	11,000	29.45
Venezuela	262	17,000	64.72	148	7,890	53.43
Other	5	191 r	42.30 r	11	309	27.05
Total	11,800	371,000	31.53	13,000	532,000	40.92
Type of product:						
Concentrates	1,060	24,700	23.38	1,250	36,400	29.06
Coarse ores	68	2,600	38.10	56	2,030	36.37
Fine ores	3,230	74,700	23.14	4,880	153,000	31.36
Pellets	7,270	256,000	35.20	6,730	337,000	50.12
Briquettes	56	10,500	188.39	--	--	--
Other agglomerates	75	2,070	27.48	74	2,820	38.24
Roasted pyrites	9	373	43.84	8	335	39.61
Total	11,800	371,000	31.53	13,000	532,000	40.92

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.

[2]Includes agglomerates.

[3]Unit values shown are calculated from unrounded data.

[4]Weighted average calculated from unrounded data by dividing total value by total tonnage.

[5]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 11
U.S. IMPORTS OF IRON ORE IN 2005, BY COUNTRY AND TYPE OF PRODUCT[1, 2]

(Thousand metric tons)

Country of origin	Concentrates	Coarse ores	Fine ores	Pellets	Briquettes and other agglomerates	Roasted pyrites	Total
Australia	--	--	1	--	--	--	1
Brazil	212	--	2,070	1,900	--	--	4,180
Canada	703	--	2,020	4,730	50	--	7,510
Chile	270	--	--	--	--	--	270
Finland	--	3	--	--	--	6	9
Mexico	--	--	23	--	18	--	41
Peru	(3)	--	31	--	--	2	33
Sweden	67	35	31	--	--	--	133
Venezuela	--	14	134	--	--	--	148
Other	(3)	4	564	99	6	(3)	674
Total	1,250	56	4,880	6,730	74	8	13,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes agglomerates.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 12
AVERAGE UNIT VALUE FOR SELECTED IMPORTS OF IRON ORE IN 2005[1]

Type of product	Country of origin	Average unit value[2] (dollars per metric ton, gross weight)
Concentrates	Brazil	30.62
Do.	Canada	22.41
Do.	Chile	39.56
Fine ores	Brazil	31.68
Do.	Canada	29.22
Pellets	Brazil	55.96
Do.	Canada	47.02

[1]Includes agglomerates.

[2]Weighted averages of individual customs values.

Source: U.S. Census Bureau.

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TABLE 13

U.S. IMPORTS OF IRON ORE, BY CUSTOMS DISTRICT[1, 2]

(Thousand metric tons and thousand dollars)

	2004		2005	
Customs district	Quantity	Value	Quantity	Value
Baltimore, MD	3,580	115,000	3,440	156,000
Buffalo, NY	9	148	6	110
Charleston, SC	1	55	2	81
Chicago, IL	1,450	31,300	1,400	39,400
Cleveland, OH	2,440	78,000	3,080	123,000
Detroit, MI	174	6,570	258	13,900
Houston, TX	57	1,590	78	3,950
Mobile, AL	84	2,900	66	2,480
New Orleans, LA	3,900	132,000	4,610	191,000
Nogales, AZ	(3)	10	18	438
Philadelphia, PA	58	2,900	22	1,560
Other	9 r	330 r	11	411
Total	11,800	371,000	13,000	532,000

rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes agglomerates.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 14

U.S. IMPORTS OF PELLETS, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

	2004		2005	
Country	Quantity	Value	Quantity	Value
Brazil	2,720	93,100	1,900	106,000
Canada	4,480	157,000	4,730	223,000
Finland	65	5,740	--	--
Russia	--	--	99	8,550
Total	7,270	256,000	6,730	337,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 15

SELECTED PRICES FOR IRON ORE IN THE JAPANESE MARKET[1]

(Cents per dry long ton unit of iron unless otherwise specified)

Country and producer	Ore types	April 1-March 31 Fiscal year 2004	Fiscal year 2005
Australia:			
Hamersley Iron Proprietary Limited and Mount Newman Mining Company Proprietary Limited	Lump ore	45.93	78.77
Do.	Fines	35.99	61.72
Robe River Iron Associates	do.	28.69	49.20
BHP Billiton (Yandi)	do.	33.83	58.02
Brazil:			
Companhia Nipo-Brasileira de Pelotizacao (Nibrasco)	Pellet feed	60.02	112.04
Companhia Vale do Rio Doce (Carajás)	Fines	32.76	56.18
Companhia Vale do Rio Doce (Itabira)	do.	32.27	55.34
Mineraçoes Brasileiras Reunidas Societe Anonyme	Lump ore	34.78	59.65
Do.	Fines	33.42	57.32
Samarco Mineracâo Societe Anonyme	Pellet feed	27.71 r	47.52
Canada, Iron Ore Company of Canada (Carol Lake)	Concentrates	31.80	54.54
Chile:			
Minera del Pacifico Societe Anonyme (Huasco)	Pellets	59.10	110.32
Minera del Pacifico Societe Anonyme (El Romeral)	Fines	29.51	50.61
India:			
Minerals and Metals Trading Corporation (Bailadila)	Lump ore	45.25	77.60
Do.	Fines	35.10	60.20
Peru, Shougang Hierro Peru S.A.A.	Pellet feed	25.08	43.01
South Africa			
Kumba Resources Limited (Iscor) cents per dry metric ton unit	Lump ore	37.78	64.79
Do. do.	Fines	27.82 r	NA

rRevised. NA Not available.

[1]Free on board shipping port basis.

Sources: Trust Fund Project on Iron Ore Information, The Iron Ore Market 2004-2006. The TEX Report Ltd., Iron Ore Manual 2005.

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TABLE 16

IRON ORE: WORLD PRODUCTION, BY COUNTRY[1]

(Thousand metric tons)

Country[4]	Gross weight[2]					Metal content[3]				
	2001	2002	2003	2004	2005[e]	2001	2002	2003	2004	2005[e]
Algeria	1,291	1,202	1,378	1,554 r	1,579	650	610	700	780 r, e	790
Australia	181,553	187,219 r	212,881 r	234,002 r	261,706 5	112,592	116,355 r	132,195 r	145,287 r	162,527 5
Austria[e]	1,800	1,900	2,119 5	1,882 r, 5	2,000	575	575	703 5	602 r	640
Azerbaijan[e]	NA	(6)	3 5	19 r, 5	7 5	NA	(6)	2	10 r	4
Bosnia and Herzegovina	264	212	127	300 r, e	3,000	132	106	63	150 r, e	1,500
Brazil	201,430	214,560	234,478 r	262,029 r	280,000 p	133,713	142,468	155,693	174,300 r	185,000 p
Bulgaria	464	373	466	83 r	80	148	119	127	27 r	26
Canada[7]	27,119	30,902	33,322	28,596 r	30,125 p	17,274	19,684	20,993	18,016 r	18,980 p
Chile	8,834	7,269	8,011	8,003 r	8,000	5,437	4,398	4,865	4,850 r	4,800
China[e, 8]	220,000	231,000	261,000	320,000 r	420,000	72,600	76,200	86,000	105,000 r	138,000
Colombia	637	688	625	508 r	499 5	350	378	344 e	280 r, e	275
Egypt	2,600	2,618 r	2,237 r	2,400 r, e	2,600	1,300	1,309 r, e	1,119 r, e	1,200 r, e	1,300
Germany[9]	407 e	419 e	429 e	412	410	57 r	59 r	60 r	58 r	57
Greece[e, 10]	1,500	1,500	1,500	1,500	1,500	575	575	575	575	575
Guatemala	15 e	35	2 r	3 r	11 5	10	23	2 r	2 r	7
India	79,200	86,400	99,100	120,600	140,000 5	50,700	55,300	63,400	77,200 e	90,000
Indonesia	469	379	245	90	22 5	258 e	216 e	140 e	51 e	12
Iran[11]	13,978 r	16,906 r	18,287 r	18,205 r	19,000	6,400 r	8,000 r	9,000 r	8,900 r	9,000
Japan	1	-- r	-- r	-- r	--	(6)	-- r	-- r	-- r	--
Kazakhstan	14,140	15,423	19,281 r	18,726 r	16,470 5	8,000	8,700	10,933	10,600 r	9,300
Kenya	1	1	1	1	1	(6)	(6)	(6)	(6)	(6)
Korea, North[e]	4,200	4,100	4,430	4,580	5,000	1,200	1,150	1,260	1,300	1,400
Korea, Republic of	195	365	289 r	328 r	305 5	109	164	125 r	138 r	131 5
Macedonia[e]	10 r	10 r	10 r	10 r	10	6 r	6 r	6 r	6 r	6
Malaysia	376	404	597	664 r	650	241 e	259 e	382	424 r	416
Mauritania	10,302	9,553	10,377 r	11,000 r	11,000	6,700	6,200	6,890 r	7,200 r	7,200
Mexico[12]	8,783	9,941 r	11,265 r	11,483 r	11,700	5,270	5,965	6,759	6,890	7,028 5
Morocco	8	9	6 r	10 r	10	4	5	3 r, e	5 r, e	5
New Zealand[13]	1,636 5	1,740 5	1,947 5	2,329 r, 5	2,300	480	520	580 e	690 r	690
Nigeria	25	25	-- e	-- e	--	9	9	-- e	-- e	--
Norway	500	515	500	600	620	340 e	350	340	408	420
Peru	4,564	4,594	5,229 r	6,439	6,895 5	3,087	3,105	3,542	4,247 r	4,565 5
Portugal[14]	15 5	15	15 5	12	12	5	5	5	4	4
Romania[e]	292	341	304	305 r	300	76	89 5	82 5	74 5	70 5
Russia	82,500	84,236	91,760	96,980	96,764 5	48,000 e	49,000	53,000 e	56,200 e	56,100
Slovakia	435	326	287 r	305 r	300	152	114	100 r, e	107 r, e	105
South Africa[15]	34,757	36,484	38,086	39,322 r	39,542 5	22,240	23,350	24,000 e	24,800 e	24,900
Sweden	19,486 5	20,300	21,500	22,300	23,300	12,811 5	13,400 5	14,100	14,700	15,300
Thailand	(6)	570	10	136	220 5	(6)	285	5 e	68 r, e	116 5
Tunisia	204	198	164	244	206 5	109 e	105	87 e	129	110
Turkey	3,932	3,433	3,429	3,857	4,000 5	2,100 e	1,830 r, e	1,830 r, e	2,060 r, e	2,150
Uganda	1	--	--	--	--	1	--	--	--	--
Ukraine	54,650	58,900	62,498	65,550	68,570 5	30,000 e	32,300	34,300 e	36,000 e	37,700
United Kingdom	1 5	1 5	1	1	1	1	(6)	(6)	(6)	(6)
United States	46,192	51,570	48,554	54,724	54,329 5	29,263	32,499	30,590	34,460	34,202 5
Venezuela[16]	16,902	16,684	17,954	19,196 r	20,000	10,817	11,092 r	11,936 r	12,669 r	13,000
Vietnam	400 r	430 r	540 r	650 r	700	220 r	236 r	300 r	360 r	385
Zimbabwe	361	272	367	283 r	377 5	180 r, e	136 r, e	180 r, e	154 r, e	200
Total	1,046,430 r	1,104,022 r	1,215,610 r	1,360,221 r	1,534,121	584,192 r	617,249 r	677,315 r	750,981 r	828,996

See footnotes at end of table.

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TABLE 16—Continued
IRON ORE: WORLD PRODUCTION, BY COUNTRY[1]

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available. -- Zero.

[1]Table includes data available through July 16, 2006.

[2]Insofar as availability of sources permit, gross weight in this table represent the nonduplicative sum of marketable direct-shipping iron ores and iron ore concentrates; iron agglomerates produced from imported iron ores have been excluded under the assumption that the ore from which such materials are produced has been credited as marketable ore in the country where it was mined.

[3]Data represent actual reported weight of contained metal or are calculated from reported metal content. Estimated figures are based on latest available iron content reported, except for the following countries for which grades are U.S. Geological Survey estimates: Azerbaijan, Kazakhstan, North Korea, and Ukraine.

[4]In addition to the countries listed, Cuba may also produce iron ore, but definitive information on output levels, if any, is not available.

[5]Reported figure.

[6]Less than ½ unit.

[7]Series represented gross weight and metal content of usable iron ore (including byproduct ore) actually produced, natural weight.

[8]China's gross weight iron ore production figures are significantly higher than that of other countries, because China reports crude ore production only with an average iron content of 33%, whereas other countries report production of usable ore.

[9]Iron ore is used domestically as an additive in cement and other construction materials but is of too low a grade to use in the steel industry.

[10]Nickeliferous iron ore.

[11]Data are for year beginning March 21 of that stated.

[12]Gross weight calculated from reported iron content based on grade of 60% iron.

[13]Concentrates from titaniferous magnetite beach sands.

[14]Includes manganiferous iron ore.

[15]Includes magnetite ore as follows, in thousand metric tons: 2001—2,552; 2002—2,557; 2003—2,307; 2004—2,893; and 2005—2,900.

[16]Offical data reported by the Ministerio de la Industria Básica y Minería (formerly Ministerio de Energía y Minas), may differ from those published by Venezuela's only producer C.V.G. Ferrominera Orinoco CA.

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TABLE 17
IRON ORE: WORLD PELLETIZING CAPACITY,
BY CONTINENT AND COUNTRY IN 2005[1]

	Rated capacity, gross weight (million metric tons)
North America:	
Canada	27.5 e
Mexico	12.0 e
United States	55.6
Total	95.1
South America:	
Brazil	53.0 e
Chile	5.2
Peru	3.5 e
Venezuela	10.5 e
Total	72.2
Europe:	
Netherlands	4.6 e
Russia[2]	65.0 e
Slovakia	0.5 e
Sweden	16.5
Turkey	1.5 e
Total	88.1
Asia:	
Bahrain	4.0
China	47.0 e
India	12.8
Iran	9.0 e
Japan	4.0 e
Total	76.8
Oceania, Australia	6.0 e
Grand total	338.2

eEstimated.
[1]Data may not add to totals shown because of independent rounding.
[2]Includes Kazakhstan and Ukraine.

Sources: International Iron and Steel Instuitute; United Nations Commission on Trade and Development, Trust Fund on Iron Ore Information; U.S. Geological Survey.

TABLE 18
IRON ORE-PRODUCING MINES IN THE UNITED STATES IN 2005

State and mine	County	Operator	Source of iron ore
California, Dredge 21	Yuba	Cal Sierra Development Inc.	Dredged sands.
Michigan:			
Empire	Marquette	Cleveland-Cliffs Inc	Magnetite taconite ore.
Tilden	do.	do.	Hematite-magnetite taconite ore.
Minnesota:			
Hibbing Taconite	St. Louis	do.	Magnetite taconite ore.
Keewatin Taconite	do.	United States Steel Corporation	Do.
Minntac	do.	do.	Do.
Minorca	do.	Mittal Steel Corporation	Do.
Northshore	do.	Cleveland-Cliffs Inc	Do.
United Taconite	do.	do.	Do.

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Iron Oxide Pigments

By Michael J. Potter

Domestic survey data were prepared by Benjamin S. Goff, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

In 2005, total iron oxide pigment (IOP) production, using partially estimated data, increased by 6% to 90,000 metric tons (t) valued at $93.4 million. Exports of IOPs decreased to 2,220 t valued at $6.2 million. IOP imports increased by 14% to 193,000 t with China as the leading supplier.

Natural iron oxide pigments are derived from hematite, which is a red iron oxide mineral; limonites, which vary from yellow to brown, such as ochers, siennas, and umbers; and magnetite, which is black iron oxide. Synthetic iron oxide pigments are produced from basic chemicals. The three major methods for the manufacture of synthetic iron oxides are thermal decomposition of iron salts or iron compounds; precipitation of iron salts, usually accompanied by oxidation; and reduction of organic compounds by iron (Podolsky and Reid, 2006, p. 1458).

Production

U.S. production data for crude (natural) IOPs sold or used in 2005 were developed by the U.S. Geological Survey (USGS) from a voluntary survey of four companies, of which three responded. Data are withheld to avoid disclosing company proprietary data. In a second voluntary survey, data were received from 6 of 12 known processing operations for finished (natural and synthetic) IOPs. By tonnage, the six operations represented 47% of the output in tables 1 and 2. Data for nonrespondents were estimated on the basis of prior-year levels of output.

At least three U.S. companies produced regenerated iron oxide, which is obtained when spent pickle liquor from steelmaking is treated (table 3). Regenerator iron oxide data were not included in tables 1 and 2. A major end use for this material was ferrites, which are magnetic ceramic oxides. There are two types of ferrites—soft, which do not retain permanent magnetism, and hard, which retain permanent magnetism. Uses of soft ferrites include computers, cores for radio frequency coils, inverter cores, memory cores, microwave communication systems, microwave ferrites for telecommunications, pot cores, rectangular modulus cores, television deflection yokes, and other industrial applications. Hard ferrites are used in flexible magnets, generators, loudspeakers, and motors.

Elementis Pigments Inc. (a division of Elementis plc) scaled down production of IOPs at its East St. Louis, IL, plant and transferred production to its recently commissioned plant in Tai Cang, China. Other production was to be accommodated at its Easton, PA, plant. The company noted that its coatings market showed growth in Asia but demand was relatively flat in Europe and the United States (Industrial Minerals, 2005a; Elementis plc, 2006§[1]).

In restructuring activities, Lanxess AG announced the shutting down of its New Martinsville, WV, production of yellow IOPs. Production was to cease in mid-2006, and closing the plant's operations was to take place in 2007. In the future, customers were to be supplied from the company's operations in Porto Feliz, Brazil, and Uerdingen, Germany (Lanxess AG, undated §).

Azco Mining Inc. of Glendale, CA, reacquired 100% interest in a mineral lease with New Planet Copper Mining Co. that is claimed to contain a major occurrence of micaceous iron oxide (MIO). A major application of MIO is as an anticorrosion agent in paint. The company's proposed new operation would produce MIO pigment for domestic and overseas paint markets (Industrial Minerals, 2005b).

Consumption

Although data were not available, construction materials and paints and coatings have been the leading end uses of IOPs. Construction applications included such concrete products as block, brick, or segmental retaining wall units; mortar; paving stones; precast products of various sizes or dimensions; ready-mixed concrete; and roofing tiles. Shipments of total paint and coatings (comprising architectural coatings, original equipment manufacture product coatings, and special-purpose coatings) were approximately the same in 2005 as in 2004 (U.S. Census Bureau, 2006§).

Other end uses of IOPs included as colorants for ceramics, glass, paper, plastics, rubber, and textiles; in foundry sands; and industrial chemicals, such as catalysts. Other applications were animal feed, cosmetics, ferrites, fertilizers, and magnetic ink and toner.

Prices

Lanxess announced price increases in December of an average of 5% to 8% for its synthetic IOPs. The company cited increases in the cost of energy, fuel, and other raw materials as the reasons for the price increases (Lanxess AG, 2005§).

Effective November 1, Rockwood Pigments NA, Inc. announced plans to raise prices for its IOPs by an average of 10% and to pass on freight surcharges imposed by domestic carriers. The company noted increases in energy, raw materials, and transportation costs as the reasons for the actions (Rockwood Specialties Group, Inc., 2005§).

The average annual producer price index (PPI) for IOPs for 2005 was 191.3 compared with 180.2 in 2004. The PPI measures the average change in the selling prices charged by domestic producers of IOPs over time. The baseline for the IOP PPI is June 1983 (U.S. Bureau of Labor Statistics, 2006§).

Foreign Trade

U.S. exports of pigment-grade IOPs in 2005 totaled 2,220 t compared with 3,120 t in 2004 (table 4).

[1]References that include a section mark (§) are found in the Internet References Cited section.

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U.S. imports of IOPs of 193,000 t in 2005 were 14% higher than those of 2004 (table 5). By tonnage, the three leading sources of IOP imports were China with 60%; Germany, 22% and Italy, 5% (table 6). The average value of total U.S. imports of synthetic IOPs from China was $599 per metric ton in 2005 compared with $545 per ton in 2004. The average value of total U.S. imports of synthetic IOPs from all countries was $734 per ton in 2005 compared with $687 per ton in 2004.

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India.—Selective Minerals® Color Industries Pvt. Ltd. has been manufacturing processed minerals including natural iron oxides (black, red, and yellow), from its operation near Mumbai for more than 25 years. Production was about 15,000 metric tons per year supplying such end uses as ceramics, construction, ferrites, glass, paint, and plastics. Major export markets include Africa, Europe, the Far East, and the Middle East (Industrial Minerals, 2005c).

Sweden.—IOPs were used in the new Arsta Bridge, which opened in August, that handles train traffic to and from Stockholm's Central Station. The 833-meter-long bridge contains concrete that is colored with 350 t of red-brown IOPs, which is the traditional color of houses in Sweden (Lanxess AG, 2006§).

Outlook

During the past several years, the color pigments industry has gone through a period of restructuring, responding to the globalization of pigment markets. Other challenges include maturing markets in some applications and regions. Production of lower to medium-value IOPs could continue to shift to lower cost countries, such as China and India (Will, Schlag, and Kishi, 2004, p. 575.0000 P–575.0000 Q).

Future developments could include nanosized (less than 0.1 micron) materials and new chemical applications, with concrete/construction and paint/coatings usage continuing as dominant end uses (Podolsky and Reid, 2006, p. 1462-1463).

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TABLE 1
SALIENT U.S. IRON OXIDE PIGMENTS STATISTICS[1]

		2001	2002	2003	2004	2005
Crude pigments sold or used:[2]						
Quantity	metric tons	61,500	W	W	W	W
Value	thousands	$3,460	$1,070	W	W	W
Finished pigments sold:[3]						
Quantity	metric tons	135,000	115,000	90,000 e	85,000 e	90,000 e
Value	thousands	$130,000	$117,000	$89,000 e	$77,000 e	$93,400 e
Exports:						
Quantity	metric tons	9,100	6,270	4,500	3,120	2,220
Value	thousands	$16,800	$12,100	$11,000	$7,380	$6,170
Imports for consumption:						
Quantity	metric tons	89,900	132,000	140,000	170,000	193,000
Value	thousands	$76,900	$96,300	$96,600	$116,000	$140,000

eEstimated. W Withheld to avoid disclosing company proprietary data.
[1]Data are rounded to no more than three significant digits.
[2]Mined.
[3]Natural (mined) and synthetic.

TABLE 2
FINISHED IRON OXIDE PIGMENTS SOLD BY PROCESSORS IN THE UNITED STATES, BY KIND[1]

	2004		2005	
Kind	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Natural:				
Black, magnetite	W	W	W	W
Umbers:				
Burnt	W	W	W	W
Raw	W	W	W	W
Red, iron oxide[2]	W	W	W	W
Undistributed and other[3]	52,000	$20,000	52,000	$22,600
Total e	52,000	20,000	52,000	22,600
Synthetic:				
Black, iron oxide	--	--	W	W
Brown, iron oxide	W	W	W	W
Red, iron oxide	W	W	W	W
Yellow, iron oxide	21,300	35,600	22,800 e	36,600 e
Mixtures of natural and synthetic, iron oxides	W	W	W	W
Total	32,300	57,700	38,000 e	70,800 e
Grand total e	85,000	77,000	90,000	93,400

eEstimated. W Withheld to avoid disclosing company proprietary data; included with "Natural, undistributed and other" and "Synthetic, total." -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes pyrite cinder.
[3]Includes brown burnt sienna, ocher, raw sienna, and data indicated by symbol W.

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TABLE 3
PRODUCERS OF IRON OXIDE PIGMENTS AND REGENERATOR IRON OXIDES IN THE UNITED STATES IN 2005

Producers	Plant location
Finished pigments:	
Alabama Pigments Co.	Green Pond, AL.
Dynamic Color Solutions, Inc.	Milwaukee, WI.
Elementis Pigments Inc.	East St. Louis, IL; and Easton, PA.
Hoover Color Corp.	Hiwassee, VA.
Lanxess Corp.	New Martinsville, WV.
New Riverside Ochre Co., Inc.	Cartersville, GA.
Prince Manufacturing Co., Inc.	Quincy, IL; and Bowmanstown, PA.
Rockwood Pigments Inc.	Beltsville, MD; and St. Louis, MO.
Solomon Grind-Chem Services Inc.	Springfield, IL.
Crude pigments:	
Alabama Pigments Co.	Green Pond, AL.
Cleveland-Cliffs Iron Co., Mather Mine and Pioneer plant[1]	Negaunee, MI.
Hoover Color Corp.	Hiwassee, VA.
New Riverside Ochre Co., Inc.	Cartersville, GA.
Regenerator iron oxides:	
Bailey-PVS Oxides, L.L.C.	Decatur, AL; Fairfield, AL; Delta, OH.
International Steel Services, Inc.	Allenport, PA.
Weirton Steel Corp.	Weirton, WV.

[1]Closed July 31, 1979; shipping from stockpile.

TABLE 4
U.S. EXPORTS OF IRON OXIDES AND HYDROXIDES, BY COUNTRY[1]

	2004				2005			
	Pigment grade		Other grade		Pigment grade		Other grade	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Australia	17	$70	308	$595	1	$6	250	$577
Belgium	492	1,920	68	152	442	1,480	115	297
Brazil	16	90	232	254	76	377	93	294
Canada	39	50	11,100	12,600	26	39	10,300	11,700
China	219	275	43,600	8,080	299	469	43,800	12,700
Colombia	19	60	151	67	7	17	237	90
France	275	839	355	946	4	58	438	1,110
Germany	17	33	260	650	13	16	509	1,040
Hong Kong	84	109	1,500	2,040	85	194	2,490	1,810
India	170	349	320	311	85	179	308	332
Indonesia	46	37	115	207	--	--	113	132
Italy	--	--	1,910	1,240	19	44	785	835
Japan	52	80	710	500	37	27	980	1,260
Korea, Republic of	445	584	1,950	2,220	27	190	3,360	3,050
Malaysia	--	--	287	698		8	440	864
Mexico	437	492	1,690	1,610	174	295	1,260	951
Netherlands	8	20	643	1,180		3	439	845
Russia	296	668	220	411	195	345	246	413
Singapore	1	6	994	383	--	--	1,380	382
Taiwan	--	--	2,170	1,650	19	107	1,460	1,800
Thailand	18	29	918	334	--	--	890	348
United Kingdom	134	329	2,420	4,710	167	601	1,870	4,210
Other	335	1,350	769	1,050	548	1,710	1,290	2,100
Total	3,120	7,380	72,700	41,800	2,220	6,170	73,100	47,100

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF SELECTED IRON OXIDE PIGMENTS, BY TYPE[1]

Type	2004 Quantity (metric tons)	2004 Value[2] (thousands)	2005 Quantity (metric tons)	2005 Value[2] (thousands)	Principal sources, 2005 (metric tons)
Natural:					
Earth colors[3]	3,270	$1,410	3,780	$1,700	Cyprus, 3,480; Spain, 235; Germany, 68.
Micaceous	833	690	1,420	896	Spain, 794; France, 253; Austria, 219.
Total	4,100	2,100	5,200	2,590	
Synthetic:					
Black	41,700	31,100	48,600	35,700	China, 20,500; Germany, 17,100; Italy, 5,060 Canada, 2,440; Japan, 1,970; Mexico, 644; India, 542; Egypt, 156; Republic of Korea, 110.
Red	67,900	41,200	74,400	47,400	China, 52,700; Germany, 14,700; Italy, 1,540; Canada, 1,070; Japan, 906; Colombia, 511; Belgium, 502; Sweden, 327; Brazil, 177.
Yellow	52,600	36,700	61,500	49,400	China, 42,000; Germany, 9,920; Brazil, 3,900; Italy, 2,670; Colombia, 1,130; Mexico, 816; Canada, 527; India, 182; Hong Kong, 162.
Other[4]	3,330	4,950	3,360	5,030	China, 1,810; Canada, 551; Germany, 448; Japan, 414; France, 70.
Total	166,000	114,000	188,000	138,000	
Grand total	170,000	116,000	193,000	140,000	

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Customs value.
[3]Includes those earth colors not elsewhere specified or included.
[4]Includes synthetic brown oxides, transparent oxides, and magnetic and precursor oxides.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF IRON OXIDE AND IRON HYDROXIDE PIGMENTS, BY COUNTRY[1]

Country	Natural 2004 Quantity (metric tons)	Natural 2004 Value[2] (thousands)	Natural 2005 Quantity (metric tons)	Natural 2005 Value[2] (thousands)	Synthetic 2004 Quantity (metric tons)	Synthetic 2004 Value[2] (thousands)	Synthetic 2005 Quantity (metric tons)	Synthetic 2005 Value[2] (thousands)
Austria	307	$309	219	$212	--	--	--	--
Belgium	9	12	--	--	533	$437	1,730	$612
Brazil	--	--	--	--	3,020	2,520	4,070	3,740
Canada	--	--	--	--	1,970	3,230	4,580	5,610
China	--	--	16	63	96,800	52,800	117,000	70,100
Colombia	--	--	--	--	1,190	1,330	1,680	2,040
Cyprus	3,030	1,230	3,480	1,510	20	10	--	--
France	54	32	253	167	246	818	196	830
Germany	197	239	106	136	43,700	29,600	42,200	33,100
Hong Kong	--	--	--	--	1,200	638	343	239
India	11	6	--	--	2,240	1,380	831	469
Italy	--	--	18	11	7,620	8,750	9,270	11,200
Japan	59	102	79	135	2,800	7,810	3,310	5,970
Mexico	--	--			2,540	2,200	1,550	1,530
Spain	279	87	1,030	362	418	202	145	75
Sweden	--	--	--	--	750	175	327	117
United Kingdom	--	--	--	--	274	1,840	211	1,690
Other	155	86	--	--	203	129	429	432
Total	4,100	2,100	5,200	2,600	166,000	114,000	188,000	138,000

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Customs value.

Source: U.S. Census Bureau.

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TABLE 7

NATURAL IRON OXIDE PIGMENTS: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005
Austria	5,000	5,000	5,000	4,000	4,000
Brazil	2,000	2,000	2,000	2,000	2,000
Cyprus, umber	7,800 [4]	8,200 [4]	11,900 [4]	12,000	12,000
France	1,000	1,000	1,000	1,000	1,000
Germany	400	419 [4]	429 [4]	400 [r]	400
Honduras	70,941	71,000	71,000	71,000	71,000
India, ocher	355,000	360,000	365,000	360,000	360,000
Iran	1,000 [4]	2,300 [4]	2,300	2,500	2,500
Italy	500	500	500	500	500
Pakistan, ocher	4,800	4,500	4,500	4,500	4,500
Paraguay, ocher	300	300	250 [r]	250 [r]	250
South Africa	852 [4]	252 [4]	764 [r, 4]	512 [r, 4]	555 [4]
Spain, ocher	87,000	80,000	80,000	75,000	75,000
United States	61,500 [4]	W	W	W	W

[r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Estimated data are rounded to no more than three significant digits.

[2]Table includes data available through June 4, 2006.

[3]In addition to the countries listed, a number of others undoubtedly produce iron oxide pigments, but output is not reported and no basis is available for formulating estimates of output levels. Such countries include Azerbaijan, China, Kazakhstan, Russia, Turkey, and Ukraine. Unreported output is probably substantial.

[4]Reported figure.

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KYANITE AND RELATED MATERIALS

By Michael J. Potter

Domestic survey data and tables were prepared by Elsie D. Isaac, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

Kyanite output in the United States was an estimated 90,000 metric tons (t) in 2005; the United States was the world's leading producer of this mineral (table 3). Production of synthetic mullite in the United States was an estimated 40,000 t. There was no reported U.S. production of sillimanite. Andalusite was mined and marketed as part of a mineral mixture in the United States, but data are withheld to avoid disclosing company proprietary data. Refractory products continued to be a major end use for kyanite and related materials.

This report includes information on kyanite, andalusite, and sillimanite (all of which have the formula Al_2SiO_5) and mullite (Al_6SiO_{13}). Mullite is an aluminosilicate mineral that occurs in nature, although rarely, and also is made by calcining other minerals, such as kyanite. Synthetic mullite in this report refers to mullite that is made by calcining at high temperature certain alumina- and silica-containing minerals other than kyanite, such as bauxite and kaolin.

Production

Kyanite Mining Corp. (KMC), the sole U.S. producer of kyanite and kyanite-derived mullite, operated two open pit mines in Buckingham County, VA, and beneficiated the ore into a marketable kyanite concentrate. The company also had two kilns at its Dillwyn, VA, facility for production of mullite. Reported U.S. production data collected by the U.S. Geological Survey (USGS) are withheld to avoid disclosing company proprietary data. Estimated U.S. kyanite production in 2005, based on nongovernment estimates from previous years, was about 90,000 t with a value of about $13 million. KMC calcined some of its kyanite in excess of 1,450° C to yield mullite, a refractory (heat-resistant) material. KMC's mullite product contained about 80% mullite (Kyanite Mining Corp., 2006§[1]). Synthetic mullite, made from calcined bauxitic kaolin and sold by C-E Minerals, Inc. contained 87% mullite and was produced near Americus, GA (C-E Minerals, 2006§). Estimated U.S. production of synthetic mullite was about 40,000 t in 2005 (Dickson, 2006§); the estimated value for the material was about $9.7 million.

Piedmont Minerals Co., Inc. in Hillsborough, NC, mined a deposit containing andalusite combined with pyrophyllite and sericite. The company sold products containing blends of the three minerals to producers of refractories and ceramics.

Consumption

Kyanite increases in volume by 16% to 18% when calcined to mullite and can be used in its raw concentrate form in a refractory mixture to offset the shrinkage on firing of other components, especially clays. Mullite is abrasion- and slag-resistant. It also has good creep resistance, which is resistance to physical deformation under load at high temperatures. Andalusite expands irreversibly by only about 4% to 6% when calcined and can therefore be used directly in refractories in its raw state. The small-volume increase can be beneficial; calcining the refractory in service can result in tight-fitting refractory linings (Spears, 2005; Dickson, 2006§). In other refractory applications, kyanite concentrate is calcined to mullite before being added to refractory mixes if the volume increase of the kyanite is not required in the mix (Roskill Information Services Ltd., 1990, p. 56).

Examples of refractories that contain andalusite, kyanite, and/or mullite include insulating brick, firebrick, kiln furniture, refractory shapes, and monolithic refractories (made of a single piece or as a continuous structure) including castables (refractory concrete), gunning mixes, mortars, plastics, and ramming mixes. The interlocking grain structure of andalusite, kyanite, and mullite gives added mechanical strength to refractories and other nonrefractory ceramic articles. Other end uses of kyanite and related materials include brake shoes and pads, electrical porcelain, foundry use, precision casting molds, sanitaryware, and other products (Kyanite Mining Corp., 2006§).

Monolithic refractories are a major end use of kyanite (Kyanite Mining Corp., 2006§). Monolithic refractories are supplied in unfired, generally unshaped form in contrast to prefired, preshaped brick products. They include a wide variety of products that may be gunned, hand packed, moulded, poured, pumped, rammed, or vibrated into place. Monolithic refractories are used in many of the same consuming industries as brick, including aluminum furnaces, foundry (both ferrous and nonferrous), incineration, iron and steel production, petrochemicals, power generation, and other applications (Moore, 2004).

Iron and steel production continued to be the leading user of refractories worldwide. U.S. crude steel production decreased by about 6% in 2005 from that of the previous year. World crude steel production increased by 5.8% in 2005 compared with that of 2004 (International Iron and Steel Institute, 2006§).

Foreign Trade

The United States exported kyanite and mullite to countries in Europe, Latin America, the Pacific rim, and other areas. More than one-third of U.S. kyanite output was exported (Dickson, 2006§). Most of the material imported into the United States in 2005 was from South Africa and was presumed to be andalusite (table 2). No U.S. imports of kyanite or sillimanite were reported in 2005.

[1]References that include a section mark (§) are found in the Internet References Cited section.

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South Africa continued to be the leading producing country of andalusite, with an estimated 235,000 t in 2005. France produced an estimated 65,000 t of andalusite. Although the USGS has not obtained official production data, China appears to be a producer of kyanite and related minerals (Dickson, 2006§). Using available data, India has been the predominant producer of sillimanite, with an estimated annual production of 12,000 to 14,000 t in recent years.

Countries that are said to be producers of mullite (sintered mullite and/or fused mullite) include Brazil, China, Germany, Hungary, and Japan (Taylor, 2005b).

China.—China was the leading steel producer with about 31% of the world's crude steel production in 2005 (International Iron and Steel Institute, 2006§). It was also, by far, the leading producer of refractories (Semler, 2006§). China's refractory industry comprises a number of relatively small local producers and some larger companies. Many purchasers of refractories in China typically bought the cheapest usable product possible. However, this attitude was beginning to change, with steel producers willing to accept higher priced refractory products that are higher performing and longer lasting. This results in cost benefits to their own operations (Taylor, 2005a). Continued growth in the Chinese steel industry could result in higher kyanite usage (Dickson, 2006§).

India.—India's long coastline has large deposits of beach sands that contain heavy minerals, including sillimanite. Separation and beneficiation steps can be carried out on the sands to obtain various minerals. Extensive research is being carried out for utilization of these minerals; for example, mullite aggregate was developed by reaction sintering of sillimanite sand and calcined alumina. Also, high-alumina bricks and high-temperature insulating bricks have been developed from sillimanite sand. Another potential application of the sand is in ceramic fibers, which are used as insulating material (Banergee and Banergee, 2005).

India's iron and steel and cement producers are core refractory consumers and are projected to be key sectors in the country's economic and industrial development. India's refractory sector has experienced strong growth, and there has been a trend toward increased monolithic refractories usage. A notable example of this usage is in Indian sponge iron production (Taylor, 2005a).

India relies heavily on imported refractories and refractory raw materials. In order to improve domestic product quality and keep costs down, consideration could be given to development of domestic mineral sources and processing capability to upgrade raw materials (Taylor, 2005a). Local demand for refractories could increase significantly in the future, giving incentive to further develop domestic resources to supply this growth (Dickson, 2006§).

Outlook

The use of monolithic refractories continues to increase worldwide compared with the use of bricks and shapes. This is a result of advances in installation and repair, lower price, continued improvement of the products, and environmental benefits. However, bricks and shapes still perform best in some applications. The refractories industry continues to evolve and respond to changes caused by globalization, especially the associated major increase in competition, decreasing refractories consumption by user industries in some market areas, and increased raw material and energy costs. China is the leading producer of both refractories and steel. It is projected to continue increasing production of both commodities (steel manufacturing is the leading use of refractories). The increasing consumption of refractories that began in the United States in 2004 is predicted to continue until 2009 (Semler, 2006§).

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TABLE 1
PRICE OF KYANITE AND RELATED MATERIALS IN 2005

(Dollars per metric ton)

	Price
Andalusite, free on board, Transvaal, South Africa, 57% to 58% alumina, 2,000-metric-ton bulk lots	212-248
Kyanite, USA, ex-works, calcined (mullite), 54% to 60% alumina, 18-ton lots	248-295

Source: Industrial Minerals, no. 459, December 2005, p. 71.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF ANDALUSITE, KYANITE, AND SILLIMANITE[1, 2]

Year	Quantity (metric tons)	Value[3] (thousands)
2004[4]	4,010	$1,420
2005[5]	6,300	2,410

[1]Harmonized Tariff Schedule of the United States code 2508.50.0000.
[2]Data are rounded to no more than three significant digits.
[3]Customs value.
[4]Most material is andalusite from South Africa.
[5]No kyanite or sillimanite imports were reported.

Source: U.S. Census Bureau.

TABLE 3
KYANITE AND RELATED MINERALS: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country and commodity[3]	2001	2002	2003	2004	2005
Australia:					
Kyanite	1,000	1,000	1,000	1,000	1,000
Sillimanite[4]	100	300	300	300	300
Brazil, kyanite	600	600	600	600	600
China, unspecified	3,150	3,200	3,200	3,300	3,400
France, andalusite	65,000	65,000	65,000	65,000	65,000
India:					
Kyanite	5,500	6,000	6,000	6,200	6,800
Sillimanite	13,000	14,000	14,000	14,500	15,000
South Africa, andalusite	193,225 [5]	165,087 [r, 5]	164,921 [5]	234,625 [r, 5]	235,000
Spain, andalusite	2,500	2,500	2,500	2,500	2,500
United States:[6]					
Kyanite	90,000	90,000	90,000	90,000	90,000
Mullite, synthetic	40,000	40,000	40,000	40,000	40,000
Zimbabwe, kyanite	9,682 [5]	5,657 [5]	745 [5]	210 [r, 5]	--

[r]Revised. -- Zero.
[1]U.S. and estimated data are rounded to no more than three significant digits.
[2]Owing to incomplete reporting, this table has not been totaled. Table includes data available through March 17, 2006.
[3]In addition to the countries listed, a number of other nations produce kyanite and related materials, but output is not reported quantitatively, and no reliable basis is available for estimation of output levels.
[4]In addition, about 7,000 metric tons of sillimanite clay (also called kaolinized sillimanite) that contains 40% to 48% Al_2O_3 is produced.
[5]Reported figure.
[6]Source: Dickson, Ted, 2006, Sillimanite minerals, Countries and Commodities Report, accessed March 17, 2006, via URL http://www.mining-journal.com.

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LEAD

By Peter N. Gabby

Domestic survey data and tables were prepared by Amy M. Baumgartner, statistical assistant, and the world production tables were prepared by Glenn J. Wallace, international data coordinator.

Domestic lead mine production decreased slightly compared with that of 2004. Alaska and Missouri were the dominant producing States with a 93% share. Other appreciable lead mine production was in Idaho, Montana, and Washington. Lead was produced at 10 U.S. mines employing about 860 people. The value of domestic mine production was more than $574 million. Lead concentrates produced at the Missouri mines were processed into primary metal at the only remaining domestic smelter-refinery, also located in Missouri.

Secondary lead, derived principally from scrapped lead-acid batteries, accounted for 89% of refined lead production in the United States.

Lead was consumed in about 110 U.S. plants to manufacture end-use products, including ammunition; building-construction materials; covering for power and communication cable; lead oxides in ceramics, chemicals, glass, and pigments; solders for construction, electrical/electronic components and accessories, metal containers, and motor vehicles; storage batteries; added in small amounts to some machining steel and aluminum; and used molten to cool and anneal some specialty steels.

Lead-acid batteries, including starting-lighting-ignition (SLI) and industrial types, continued to be the dominant use of lead, accounting for 88% of reported lead consumption. Shipments of replacement batteries in North America totaled 95.7 million units in 2005, a 1.5% increase from those of 2004. Shipments of automotive batteries were 21.4 million units in 2005 or 3.9% less than in 2004 (Platts Metals Week, 2006).

Monthly sales of lead from the National Defense Stockpile (NDS) totaled 29,500 metric tons (t) (32,500 short tons) in 2005, leaving 19,500 t (21,500 short tons) in uncommitted inventory in the NDS at yearend.

Lead prices increased during the year to an average of $0.443 per pound on the London Metal Exchange (LME) and $0.6103 per pound for the North American Producer price.

Legislation and Government Programs

Monthly sales of lead from the NDS continued during 2005 under the basic ordering agreement (BOA) DLA-Lead-005. The Defense National Stockpile Center's (DNSC) annual materials plan (AMP) approved by the U.S. Congress for fiscal years 2005 and 2006—the fiscal year runs from October 1 to September 30—included a maximum sales authority for lead of 54,400 t (60,000 short tons) for each fiscal year. For fiscal year 2006, the quantity to be sold will be limited to the remaining inventory, which is less than 54,400 t (Defense National Stockpile Center, 2004, 2005). BOA sales from the NDS during calendar year 2005 totaled 29,500 t. On December 31, 2005, a little more than 19,500 t (21,500 short tons) of uncommitted lead inventory remained in the NDS, down from 41,600 t (45,900 short tons) on December 31, 2004.

Production

Primary.—In 2005, domestic mine production of recoverable lead was 426,000 t, a decrease of 4,000 t compared with that of 2004. The major share of the U.S. mine output of lead continued to be derived from production in Alaska and Missouri. Lead mine production also was reported in Idaho, Montana, and Washington. Domestic mine production data were collected by the U.S. Geological Survey (USGS) from a precious-metal and base-metal voluntary survey on lode-mine production. All lead-producing mines responded to the survey. The lead concentrates produced from the mined ore were processed into primary metal at one domestic smelter-refinery in Missouri (tables 1-4).

Doe Run Resources Corp., St. Louis, MO, produced primary lead at one smelter-refinery facility in Missouri—the Herculaneum smelter. Concentrates for the smelter-refinery were provided mainly from the Doe Run mills—Brushy Creek, Buick, Fletcher, and Sweetwater. During 2005, these mills were supplied ore from production shafts—Brushy Creek, Buick, Fletcher, Sweetwater, Viburnum #29, and Viburnum #35 mine shafts—located along the mineralized Viburnum Trend in southeastern Missouri. In 2005, Doe Run's U.S. operations shipped 294,000 t of refined lead metal and lead alloy products, including lead recycled for customers (tolling). In addition, the U.S. operations shipped 138,000 t of lead concentrates to international metal trading companies in 2005. As of October 31, 2005, Doe Run's proven and probable ore reserves in the United States reportedly were 34 Mt, containing an estimated 2.14 Mt of lead, 0.47 Mt of zinc, and 0.09 Mt of copper. A major development project was started at the southern end of Doe Run's Fletcher Mine to access an ore body known as RC Westfork. This development project was expected to be completed in 2006 (Doe Run Resources Corporation, 2006§[1]).

Teck Cominco Alaska Inc. (a wholly owned subsidiary of Teck Cominco Limited, Vancouver, British Columbia, Canada) operated the Red Dog zinc-lead Mine in northwestern Alaska under a leasing agreement with NANA Regional Corp., the sole owner of the property. NANA is a corporation organized under the provisions of the Alaska Native Claims Settlement Act. During 2005, production of lead in concentrate at Red Dog decreased by 13.5% to 102,000 t compared with 117,900 t in 2004. The average mill recovery of lead at Red Dog was 59.0% in 2005 compared with 65.9% in 2004. Proven ore reserves at Red Dog, as of December 31, 2005, reportedly were estimated to be 19.5 Mt grading 20.5% zinc and 5.7% lead (Teck Cominco Limited, 2006§).

Teck Cominco's Pend Oreille zinc-lead mine near Metaline Falls, WA, produced 8,000 t of lead in concentrates in 2005.

[1]References that include a section mark (§) are found in the Internet References Cited section.

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Proven and probable ore reserves at Pend Oreille, as of December 31, 2005, reportedly were estimated to be 4.3 Mt grading 7.1% zinc and 1.3% lead; an additional, more speculative 3.3-Mt resource has been inferred at the property grading 6.6% zinc and 1.3% lead (Teck Cominco Limited, 2006§).

Hecla Mining Company, Coeur d'Alene, ID, operated the Lucky Friday Mine in Mullan, ID, throughout 2005. Lucky Friday is an underground silver-lead mine 100% owned by Hecla that has been producing since 1958. Concentrates at Lucky Friday were produced in a 1,100-metric-ton-per-day (t/d) conventional flotation mill. In 2005, ore was processed at a rate of 587 t/d, and production increased by 20% compared with that of 2004 to a level of 14,600 t of lead contained in concentrates. All silver, lead, and zinc concentrate production from the Lucky Friday operation was shipped to Teck Cominco's smelter in Trail, British Columbia, Canada, in 2005. Additional drilling of the 5900 level nearly doubled the mine's proven and probable ore reserves of lead, silver, and zinc, which were estimated to be 1.29 Mt grading 459 grams per metric ton (g/t) (reported as 13.4 troy ounces per short ton) silver, 7.7% lead, and 2.9% zinc at yearend 2005 (Hecla Mining Company, 2006§).

Hecla Mining also held a 29.7% interest in the Greens Creek Mine on Admiralty Island near Juneau, AK, through a joint-venture arrangement with Kennecott Greens Creek Mining Co. (the manager of the mine) and Kennecott Juneau Mining Company (wholly owned subsidiaries of Kennecott Minerals Company). The Greens Creek unit is a polymetallic, stratiform, massive sulfide deposit lying within the Admiralty Island Monument area and includes 17 patented lode claims and 1 patented millsite claim. In addition, it includes property leased from the U.S. Department of Agriculture's Forest Service and has title to mineral rights on 3,035 hectares of Federal land adjacent to the mine properties.

In 2005, 2,000 t/d of ore was mined (underground) and milled onsite at Greens Creek to yield lead, zinc, and bulk concentrates as well as a gold-silver dore. Total production of lead in concentrate was 21,900 t in 2005 compared with 24,800 t in 2004. Proven and probable reserves at the Greens Creek Mine at yearend 2005 reportedly were estimated to be 7.5 Mt grading 497 g/t (reported as 14.5 ounces per short ton) silver, 4.11 g/t (reported as 0.12 ounces per short ton) gold, 10.2% zinc, and 3.9% lead (Hecla Mining Company, 2006§).

Continued progress was made on identifying an underground ore body across the Gallagher Fault at the Greens Creek Mine. In addition to extensive drilling, an exploration drift was driven into the West Gallagher Zone to establish drilling platforms to define the deposit further, which already has in excess of 93 exploration holes drilled into it. In 2006, the primary exploration focus at Greens Creek will continue to be the West Gallagher Zone. In addition, significant surface reconnaissance on the rest of the property took place in 2005, and several drill targets were identified (Hecla Mining Company, 2006§).

The Greens Creek unit was powered by diesel generators located onsite. However, an agreement was reached during 2005 to purchase excess hydroelectric power from the local power company, and installation of the necessary infrastructure is expected to be complete during the first half of 2006. As a result, hydroelectric power will replace 23% to 35% of the diesel-generated power through 2008. Construction of a new hydroelectric plant by the local power company is anticipated by 2009, at which time it is estimated that it will have the capacity to supply 95% of Greens Creek power (Hecla Mining Company, 2006§).

In 2005, Apollo Gold Corp.'s Montana Tunnels open pit mine near Helena, MT, produced 1,390 kilograms (kg) (44,700 troy ounces) of gold, 16,900 kg (545,000 ounces) of silver, 4,730 t of lead, and 10,200 t of zinc. Mining was suspended in mid-October as a result of pit wall instability. Ongoing slope deformations resulted in too steep a slope between the ramps and weakening of the rock mass, which created localized instabilities along the haul ramp that reduced ramp width and increased the frequency of rock falls. On October 22, the company decided that for safety reasons, mining would stop, and Apollo Gold hired a third party consultant to review mine design criteria and determine scenarios under which mining could safely resume. During the suspension of mining, the mill produced gold dore and lead-gold and zinc-gold concentrate from low-grade ore stockpiles. After the evaluation was completed, a mine redesign was estimated to cost $12 million, and the company adopted a plan to dispose of the Montana Tunnels Mine in March 2006 (Apollo Gold Corp., 2006§).

Secondary.—Domestic secondary lead production increased by 2% in 2005, increasing to 1.14 Mt. Secondary lead accounted for 89% of domestic lead refinery production compared with 88% in 2004. Lead-acid batteries continued to be the dominant source of recoverable lead scrap, accounting for 92% of all lead produced from secondary sources. The domestic secondary statistics were derived by the USGS from a combined secondary producer and consumer survey that included data from monthly and annual surveys. Fourteen companies producing secondary lead, exclusive of that produced from copper-base scrap, were surveyed; 13 responded, representing more than 99% of the total production of secondary lead. Almost all the lead recycled in 2005 was produced by 13 companies operating 18 plants in California, Florida, Illinois, Indiana, Louisiana, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Texas. Production and consumption for the nonrespondent were estimated by using prior-year levels as a basis (tables 1, 5-9).

From 1992 to 2005, U.S. lead production from scrap has increased from 916,000 t to 1,140,000 t, a 24% increase. Scrap lead exported in 2005 was 67,300 t.

In July, Johnson Controls, Incorporated (JCI) purchased Delphi Corporation's global lead-acid battery business for $202.5 million. Excluded from the announced deal were Delphi's two U.S. manufacturing facilities, which would continue to supply batteries to General Motors Corp. through a contract with Johnson Controls. Subject to agreement between Delphi and its unions, it was anticipated that JCI would purchase Delphi's New Brunswick, NJ, operation. Pending a commercial agreement between Delphi and a customer and final discussions with the United Auto Workers Union, the Fitzgerald, GA, operation would remain with Delphi and change to a new product line at the conclusion of this transition period (Delphi Corporation, 2005§). Delphi filed for Chapter 11 bankruptcy protection in October.

The American Stock Exchange approved the stock listing of Metalico, Incorporated. Metalico, founded in 1997, has plants in

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six States fabricating lead products and recycling nonferrous and ferrous metals. Its Mayco Industries Inc., plant in Birmingham, AL, was the Nation's leading producer of nonbattery lead products (Platts Metals Week, 2005c).

Consumption

Reported U.S. consumption of lead decreased slightly in 2005. Consumption of lead in lead-acid batteries and ammunition remained essentially unchanged in 2005. Consumption in bearing metals, brass and bronze, ceramics, chemicals, paints, pigments and miscellaneous uses decreased, whereas lead consumption in sheet metal for building construction, solder, and casting metals increased. Contributing to some of the declining lead consumption categories in the United States was the relocation of some lead-consuming industries to other areas of the world.

Consumption of lead in SLI- and industrial-type lead-acid storage batteries represented 88% of the total reported consumption of lead. Industrial-type batteries included stationary batteries (such as those used in uninterruptible power-supply equipment for computer and telecommunications networks, hospitals, and load-leveling equipment for commercial electrical power systems) as well as traction batteries (such as those used in airline ground equipment, industrial forklifts, and mining vehicles) (tables 6-13).

Trade

In 2005, lead metal imports were 298,000 t, a 51% increase from those of 2004. Exports of metal declined 22% to 64,800 t.

In 2005, the United States exported 42,800 t of lead metal and 6,650 t of contained lead in mine concentrates to Mexico, and imported 17,200 t of lead metal. U.S. net exports of lead metal to Mexico were 25,600 t. In 2005, however, the U.S. also imported 14.4 million lead-acid batteries of all sizes from Mexico, 96% of which was for cars and light trucks.

Prices

LME lead prices sustained increases that began in the second half of 2003. LME monthly average prices started 2005 at $952 per metric ton, increasing to $1,005 per ton in March. The price fluctuated for the next few months and reached a low for the year of $854 per ton in July. The monthly average price increased steadily the remainder of the year and reached $1,124 per ton in December. These sustained price increases were attributed to the continued strength of the Chinese economy and a third year of refined lead world supply deficit. The average LME and North American Producer prices increased in 2005 to $0.442 per pound and $0.610 per pound, respectively, from the average prices of $0.402 per pound and $0.5514 per pound, respectively, in 2004 (table 1).

World Industry Structure

World mine production of lead increased by 160,000 t to 3.27 Mt in 2005, or a 5% increase compared with production in 2004. Of the 38 countries in which lead was mined, 6 accounted for 82% of the world's total production. China was the leading producer, with 30% of the world total, followed by Australia, 23%; the United States, 13%; Peru, 10%; Mexico, 4%; and Canada, 2%. Production increased in 2005 in all the leading producer countries except the United States (table 14).

Worldwide reserves of lead contained in demonstrated resources in producing and nonproducing deposits at yearend were estimated to be 67 Mt by the USGS (Gabby, 2006). Reserves for the three leading producers in the world, Australia, China, and the United States, were 15 Mt, 11 Mt, and 8.1 Mt of contained lead, respectively. The reserve base (reserves plus measured and indicated resources that are marginally economic and some of those that are currently subeconomic) for Australia and China was 28 Mt and 36 Mt, respectively. The reserve base for the United States was 20 Mt. The total world reserve base at the end of 2005 was estimated to be 140 Mt.

World production of refined lead increased to 7.47 Mt in 2005 from 6.95 Mt in 2004. Other statistics for 2005, as reported by the International Lead and Zinc Study Group, were as follows: world consumption increased to 7.74 Mt from 7.28 Mt in 2004; commercial stocks of refined lead in industrialized countries were 313,000 t, or 2 weeks of consumption, at yearend 2005 compared with 299,000 t at yearend 2004 and 407,000 t at yearend 2003 (International Lead and Zinc Study Group, 2006, p. 6-21).

The structure of the lead mining and refining industries was affected by a number of changes, including the opening and development of new facilities as well as the closing, reopening, expanding, selling, restructuring, and modernizing of existing facilities.

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Australia.—In October, a large stope that was to provide production for more than 3 months at CBH Ltd.'s Endeavor Mine in New South Wales suffered a sidewall and roof failure and was lost from the production schedule. In the process, the paste backfill underground delivery system was damaged, which resulted in a 6-month delay in supply of cemented backfill for mine voids; the majority of planned production for the second half of the 2005-06 fiscal year was dependent on backfilling of voids. A restructuring of the mine began in November (CBH Ltd., 2006§).

In September, Ivernia, Inc. (Toronto, Ontario, Canada) officially opened its Magellan Mine in Western Australia. In April, Ivernia had acquired full ownership of the mine by purchasing its partner's 49% interest in the property. In 2005, 50,000 t of lead concentrates was produced at the mine. At full capacity, the mine was expected to produce 100,000 metric tons per year (t/yr) of lead in concentrates. Installation of a secondary ball mill and a second concentrate thickener were planned for 2006 to improve capacity at the mine. Installation of the second concentrate thickener was scheduled to be completed in the first quarter of 2006, and installation of secondary ball mill was scheduled for June. As of December 31, 2005, measured and indicated reserves at the Magellan deposit reportedly were estimated to be 13.9 Mt at a grade of 6.0% lead (Ivernia, Inc., 2006§).

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In April, Malaysian lead alloy producer Metal Reclamation (Industries) Sdn BdH entered into a contract with Magellan Metals to purchase 60,000 t of lead in concentrate in 2005 and 100,000 t in 2006. The company would use the concentrate to replace used lead-acid batteries as feed for Metal Reclamation's 40,000-t/yr lead smelter in Pulau Indah (Platts Metals Week, 2005f).

In August, Xstrata plc announced its intention to convert the McArthur River zinc-lead mine in the Northern Territory from an underground to an open pit operation. The open pit conversion would increase ore throughput to 1.8 Mt/yr from 1.6 Mt/yr in order to maintain current levels of concentrate production from declining ore grades and would extend the mine's life by at least 25 years (Xstrata plc, 2005). Also in August, Xstrata filed an environmental impact statement (EIS) with the Northern Territory government and, in December, submitted a supplementary EIS in response to submissions received as part of the consultation process. In February 2006, the Northern Territory Minister for the Environment and Heritage declined to recommend the approval of Xstrata's proposal; a final decision was expected in April. McArthur River Mine's current Mine Management Plan, which has been approved by the Northern Territory government's Department of Business, Industry and Resource Development, included approval for a test pit onsite to contribute ore for sampling and for processing. Approval also was received to deepen the test pit to provide additional ore in the near term (Xstrata plc, 2006§). In September, ANT Minerals Pty. Ltd. [a joint venture between Nippon Mining Holdings (60%), Mitsui & Co. (20%), and Marubeni Corp. (20%)] announced that it would sell its 25% stake in the McArthur River Mine to Xstrata, which owned 75% of the mine. The deal, which was completed in December, gave Xstrata sole ownership of the mine (Platts Metals Week, 2005g).

Operations at Xstrata's Mount Isa Lead Mine ceased on December 31, 2005, because of depletion of reserves, after operating for more than 80 years. The company's new Black Star lead-zinc mine, which was commissioned in February, produced a total of 1.4 Mt of ore during 2005 (Xstrata plc, 2006§).

Intec Ltd. began operating a 4-t/d pilot plant at the Hellyer Metals project, which officially opened in September in Burnie, Tasmania. Of the metals contained in tailings, 75% was extracted in the demonstration plant, with recoveries of 97% of the contained lead and 96% of the contained zinc in addition to high recovery levels for copper and silver. The zinc was electowon in cathodes, and the lead was recovered in the form of a lead-silver cement. A bankable feasibility study for the project was scheduled to be completed in March 2006 (Intec Ltd., 2005§).

In February, Zinifex Australia Ltd. declared a force majeure on concentrate shipments from its open pit Century Mine in northwest Queensland. An electrical fault at the semiautogeneous grinding mill forced closure of the concentration circuit. A production loss of 17,700 t of zinc in concentrate and 1,400 t of lead in concentrate took place during the 11½ day shutdown (Platts Metals Week, 2005l).

In May, Terramin Australia Ltd. announced that it had concluded a joint-partnership agreement with Zinifex, whereby Zinifex would invest up to $6 million in the Mennennie Dam project for exploration and development and earn up to a 70% share in the joint venture. The project encompasses the largest known lead-zinc and silver deposit in South Australia with almost equal proportions of lead and zinc (Terramin Australia Ltd., 2005).

Canada.—After a 2½ month strike that began in July, Teck Cominco and the unions at the company's Trail, British Columbia, operations, United Steelworkers Locals 480 and 9705, ratified the terms of a new collective agreement in October. The collective agreement, applicable to 1,235 unionized employees, was for a 3-year term from June 1, 2005, to May 31, 2008. The agreement provided for wage increases of 10%, a 12% improvement in the basic pension, enhancements to a number of benefits, and a $3,500 cash payment. As a result of the strike, refined lead production at the smelter was 69,000 t, about 19% less than that in 2004 (Teck Cominco Limited, 2005§).

China.—Preliminary Chinese refined lead metal production for 2005 was 2.39 Mt, an increase of 24% compared with that of 2004. U.S. Census Bureau data indicated that companies in the United States shipped 115,000 t of lead contained in concentrates to China (11% of China's total concentrate imports). Imports of lead and concentrates increased to 1.03 Mt in 2005 from 831,000 t in 2004 (United Nations Statistics Division, 2006§).

In December, Shenzhen Zhongjin Lingnan Nonfemet Co. Ltd., China's third leading zinc producer, was forced to close its Shaoguan smelter in Guangdong Province following a toxic spill into the Beijing River. The smelter had the capacity to produce 160,000 to 170,000 t/yr of zinc. After renovating the waste treatment systems and passing an inspection for compliance with government environmental standards, the smelter reopened in February 2006 (Beijing Antaike Information Development Co. Ltd., 2006b; Metal-Pages, 2006§).

Yuguang Gold & Lead Co. Ltd. in Henan Province completed a 60,000-t/yr refined lead upgrade and increased capacity to 310,000 t/yr. Yuguang planned to complete a 60,000-t/yr expansion at its lead recycling facilities by November 2006, which would bring the company's total lead recycling capacity to 100,000 t/yr of crude lead (Platts Metals Week, 2005k).

Production began in December at Guangxi South Nonferrous Metal Smelting's electrolytic plant in Nandan County, Guangxi Province. The smelter has the capacity to produce 80,000 t/yr of zinc and 80,000 t/yr of lead in addition to antimony, silver, and sulphuric acid. The company planned to export at least 90% of these products to Japan, the Republic of Korea, Taiwan, and the United States. Also in December, production began at Yunnan Metallurgical's nonferrous metal production facility in the Quijing Economic and Technology Development Zone, Yunnan Province. The plant had the capacity to mine and concentrate 2,000 t/d of lead and zinc ores combined, yielding 100,000 t/yr of refined lead and 100,000 t/yr of refined zinc by an electrolytic process (CRU Monitor, 2006).

In November, Panlong Lead and Zinc Mining Corp. commissioned its lead-zinc mine in China. The project has the capacity to concentrate 400 t/d of ore. The company estimated reserves of 3.87 Mt within six ore bodies. Panlong planned a two-phase project to increase the capacity of the concentrator to 800 to 1,000 t/d of ore, although no timetable for the project was given (CRU Monitor, 2005a).

In June, Zhishen Lead Industry began construction of a 100,000-t/yr lead smelter at Hanguguan Town, Lingbao City,

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in Henan Province. Construction of the oxygen bottom-blowing smelter was expected to be completed by the end of 2006, with a total investment of $35 million. Also in June, Xinhua Lead Industry began construction of the first phase of a lead smelter that is expected to produce 60,000 t/yr of lead in Wumu Village, also in Lingbao City. Completion of a second phase would add 40,000 t/yr of capacity. The aforementioned two projects are in addition to a 100,000-t/yr lead smelter, which was started in May by Xinling Lead Industry, bringing the capacity of lead smelters under construction in Lingbao City to 300,000 t/yr (CRU Monitor, 2005d).

Huludao Nonferrous Metals Group Co. Ltd., Liaoning Province, was constructing a new lead-zinc smelter. Construction of the smelter is expected to be complete by early 2006 with a planned production capacity of 30,000 t/yr lead and 60,000 t/yr zinc (CRU Monitor, 2005b).

Two firms completed secondary lead facilities in 2005. Chongqing Chunxing Alloys Co. Ltd. completed construction of a 20,000-t/yr secondary lead smelter in Chongqing Province, and Anyang Yubei Gold and Lead Co. in Henan Province completed a 50,000-t/yr plant in September. Recycled batteries were expected to be the seed material for both plants (CRU Monitor, 2005c).

To address the existing problems in China's lead and zinc industry, such as lack of raw materials, outdated technology and equipment, small plant size, and pollution, the National Development and Reform Commission conducted an investigation and released "Catalogue for Guidance of Industry Structure Adjustment 2005." According to the catalog, construction of zinc smelters with capacity less than 100,000 t/yr of zinc, lead smelters with capacity less than 50,000 t/yr of primary lead, and secondary lead smelters with capacity less than 10,000 t/yr of secondary lead will be restricted, and projects adopting backward technologies will be eliminated (Beijing Antaike Information Development Co. Ltd., 2006a, b).

At least eight lead smelters located in Anhui Province were demolished in 2005 following refusal to cease production. All these plants recycled mainly lead scrap and waste storage batteries causing severe pollution to nearby Chaohu Lake from water and gas emissions plus slag disposal. None had the required government certification or licenses and were unable to reach the standards required (CRU Monitor, 2005e, f).

Germany.—Lead and zinc smelter Sudamin Metallhuette Duisburg in Duisberg, closed completely in November because of high zinc concentrate prices and energy costs. The smelter, which produced 95,000 t/yr of refined zinc and 40,000 t/yr of lead, had ceased production in early August. The company was expected to be liquidated (CRU Monitor, 2005f).

Greece.—In October, underground operations began at Hellas Gold S.A.'s Stratoni Mine in northern Greece. In the first year of full production, the mine was expected to produce 29,000 t of lead-in-concentrate. Reserves at the mine were estimated to be 1.9 Mt at grades of 10.8% zinc, 8.1% lead, and 190 g/t silver. Production at the Stratoni lead-zinc mill resumed in September following refurbishment and was treating a 15,000-t stockpile. The mill has a capacity of 400,000 t/yr (Platts Metals Week, 2005j).

India.—Hindustan Zinc Ltd. increased estimates of reserves at its Rampura Agucha mine by 25% compared with those on March 31, 2004, which would allow the mine to continue operating for an additional 3 years. Total reserves reportedly were estimated to be 50.1 Mt grading 12.8% zinc and 1.9% lead. The company planned to continue exploration through 2006. The company's 50,000-t/yr expansion at its Chanderia lead smelter was expected to be completed in 2006 (Platts Metals Week, 2005b).

Indonesia.—Following the February release of the feasibility study on its Dairi Mine in North Sumatra, Indonesia, Australia-based Herald Resources Ltd. was planning to start concentrate shipments in 2006. The company was negotiating with two banking syndicates regarding the financing of the project. By yearend, however, financing arrangements had not been completed. After financing is completed, construction was expected to be completed in less than 18 months, and production capacity of the operation would be 220,000 t/yr of concentrate containing 70,000 t of lead and 120,000 t of zinc (Herald Resources Ltd., 2006§).

Iran.—Vancouver-based Lundin Mining Corp. purchased a 19.9% stake in Union Resources Ltd. for $3.4 million. This share purchase was expected to provide the funds needed to complete the bankable feasibility study on Union's Mehdiabad mine project in Iran and allow the company to meet the requirements for listing on London's Alternate Investment Market. Mehdiabad was considered one of the world's leading undeveloped zinc, lead, and silver deposit. A bankable feasibility study was scheduled for completion in early 2006 (Platts Metals Week, 2005e). Measured and indicated resources at the Mehdiabad deposit were estimated to be 362 Mt grading 4.2% zinc, 1.6% lead, and 35 g/t silver (Union Resources Ltd., 2006§).

Ireland.—In April, Lundin Mining acquired ARCON International Resources Plc (County Kilkenny), which owned the Galmoy zinc-lead mine, for $123 million. Combined with its other assets in Sweden, the Zinkgruvan and Storliden Mines, Lundin Mining increased its lead production capacity to 46,000 t/yr and zinc production capacity to 152,000 t/yr; the company also produced copper and silver byproducts. Lundin also announced that it planned to begin an aggressive exploration program in County Kilkenny (Platts Metals Week, 2005d).

Italy.—Glencore International AG announced that would close its ISF smelter at Porto Vesme, Sardinia, because of uneconomic technology and high coke costs. Operations were suspended in mid-February. The ISF smelter had a capacity of 85,000 t/yr of zinc and 40,000 t/yr of lead, but the bulk of the site's 120,000-t/yr lead capacity comes from the separate Kivcet smelter (Platts Metals Week, 2005i).

Japan.—Nippon Holdings Co. Ltd. planned to close its Toyoha Mine in Hokkaido in June 2006 because of depleted ore reserves. The mine had been shut since April 2005 because of an increase in water flowing into the mine. The mine is the country's only zinc mine, with a capacity of 83,000 t/yr of zinc concentrate, 9,000 t/yr of lead, and 30 t/yr of indium (Platts Metals Week, 2005h).

Kazakhstan—In March, Ural Mining-Metallurgical Co. completed the first stage of updating the lead processing systems at its smelter in Vladikavkaz. Closure of a shaft furnace and the installation of three new short drum rotary furnaces was expected to bring lead production in 2005 up to 30,000 t, an increase of 5,000 t from that in 2004 (CRU Monitor, 2005b).

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Mexico.—Mexico's lead mine production increased to 130,000 t in 2005 from 118,000 t in 2004 (table 13). Mexico exported an estimated 9% of its lead mine production as lead concentrates to be smelted and refined elsewhere. The first and second leading export trade partners in concentrates were China and Belgium, respectively. The leading export trade partners in lead metal were the United States and Venezuela (United Nations Statistics Division, 2006§).

In December, Great Panther Resources Ltd. began commercial production at its Topia silver-lead-zinc mine in Durango, which had produced from 1952 to 1999. A lead concentrate, which contains the silver and gold, and a zinc concentrate were being produced and will be shipped to Industrias Peñoles S.A. de C.V.'s smelter in Torreon, Coahuila. The company is using tailings from an old dump and stockpiled ore as feed material for the plant whose capacity is rated at 200 t/d. Great Panther planned to gradually increase throughput to this level by mid-2006 (Great Panther Resources Ltd., 2005§).

Pakistan.—In January, a consortium of Chinese companies signed a contract to borrow $54 million from the China Development Bank to finance the development of the Duddar lead and zinc mine in Pakistan. The consortium, MCC Duddar Minerals Development Co. (PVT) Ltd., was composed of China Metallurgical Construction Group Corp. (51%), Hunan Zhuzhou Non-ferrous Metals Smelter Co. Ltd. (34%), and Hunan Huangshaping Lead and Zinc Mine Co. (15%). The loan was expected to fund 80% of the total investment of $72.6 million in the project. Once completed, the mine will have the capacity to produce 100,000 t/yr of zinc concentrate and 33,000 t/yr of lead concentrate. Construction was scheduled to begin in April, with production starting by the end of 2007 (Platts Metals Week, 2005a).

Peru.—At its La Oroya lead-zinc-copper smelter, Doe Run Peru S.R. Ltd. expected to complete eight of the nine projects required by the Environmental Adjustment and Management Program (PAMA) by the end of 2009. The final project includes the construction of three sulfuric acid plants. The acid plant for the zinc circuit was expected to be completed by the end of 2006; the lead circuit by 2008; and the copper circuit by the end of 2009. The company was seeking more time to complete an additional project at the metals processing facility. The company's investment in PAMA mandated projects was expected to be $200 million (Doe Run Peru S.R. Ltd., 2006). In the fiscal year ending October 31, 2005, Doe Run Peru produced 121,000 t of refined lead, a slight increase from that in 2004 (Doe Run Resources Corporation, 2006§).

Vietnam.—The Ta Pan zinc-lead plant in Ha Giang Province began production in mid-December. The plant was constructed in early 2004 at a cost of more than $1 million, at least $750,000 of which was contributed by China. The plant has the capacity to refine 300 t/d of ore, producing 5,800 to 6,000 t/yr of refined metal for domestic consumption and export (CRU Monitor, 2006).

Outlook

World usage of refined lead is forecast to increase in 2006 and 2007. The largest increase, 3.3%, will take place in 2006. Demand in Europe is expected to remain at 2005 levels in 2006 and 2007. In the United States, demand is forecast to decline 3% in 2007 despite a slight increase in demand for lead for SLI batteries in 2006. Consumption in China is expected to increase by 10% in 2006 and 2007 because of increased domestic and export demands for lead-base batteries. Similarly, increases in consumption of lead are anticipated in India, Mexico, and Thailand. In general, regional consumption of refined lead metal has already shifted and probably will continue to shift as battery manufacturers, the major consumer of refined lead, seek out lower cost areas in which to set up manufacturing facilities.

Sales of refined lead metal for automotive batteries and industrial batteries for telecommunications and information technology industries are expected to account for an increasingly larger share of the market, as environmental concerns discourage use in other markets. Currently, SLI and industrial lead-acid batteries account for 75% to 85% of world lead usage.

On the supply side, global lead mine production was expected to increase 1.3% in 2006. Growth in 2007 was predicted to be 8.8%. Several mines that have recently reopened in Europe, along with increased output in Russia, could boost European lead production by 9.4% in 2006 and 17.2% in 2007. Increased production, 8.5% in 2006 and 10% in 2007, also is expected in China, where several new mines were commissioned.

Primarily because of increased production in China, global output of refined lead was forecast to increase by 6.1% in 2006 and 3% in 2007. A western world supply excess of 32,000 t was anticipated in 2006 (International Lead and Zinc Study Group, 2006).

Mine production in the United States declined in recent years but through July 2006 production has been 1% greater than that of 2005. As a result, U.S. mine output is expected to be unchanged or slightly greater in 2006 than in 2005. Primary refined lead production declined 49% since 2001 or 12% per year. The leveling off of this downward trend in 2005 suggests that the decline in primary U.S. refined lead production in 2006 will be much less than in recent years. Secondary production of lead increased slightly since 2001 but probably will remain unchanged or increase only slightly in 2006.

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TABLE 1
SALIENT LEAD STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Production:						
Mine, recoverable lead content:[2]						
Quantity	metric tons	450,000 r	440,000	449,000	430,000	426,000
Value	thousands	$433,000	$423,000	$433,000	$415,000	$574,000
Primary lead, refined, lead content:						
Domestic ores and base bullion	metric tons	290,000	262,000	245,000	148,000	143,000
Foreign ores and base bullion	do.	(3)	(3)	--	--	NA
Secondary lead, lead content	do.	1,090,000 r	1,100,000 r	1,140,000	1,130,000 r	1,140,000
Exports, lead content:						
Lead ore and concentrates	do.	181,000	241,000	253,000	292,000	390,000
Lead materials, excluding scrap	do.	38,100 r	43,400	123,000	82,600	64,800
Imports for consumption, lead content:						
Lead in ore and concentrates	do.	2,240	6	--	--	--
Lead in base bullion	do.	--	--	6 r	3 r	29
Lead in pigs, bars, and reclaimed scrap	do.	271,000	210,000	175,000	197,000	298,000
Stocks, December 31, lead content:						
Primary lead	do.	(4)	(4)	W	W	W
At consumers and secondary smelters	do.	100,000	111,000	84,600	59,000	64,700
Consumption of metal, primary and secondary, lead content	do.	1,550,000	1,440,000	1,390,000	1,480,000	1,460,000
Price, North American Producer average, delivered[5]	cents per pound	43.64	43.56	43.76	55.14	61.03
World:						
Production, gross weight:						
Mine	thousand metric tons	3,100,000 r	2,880,000 r	3,190,000 r	3,160,000 r	3,320,000
Refinery[6]	do.	3,400,000 r	3,400,000 r	3,330,000 r	3,340,000 r	3,730,000
Secondary refinery	do.	3,200,000 r	3,370,000 r	3,450,000 r	3,620,000 r	3,740,000
Price, London Metal Exchange, pure lead, cash average[5]	cents per pound	21.58	20.52	23.34	40.19	44.23

rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Data are rounded to no more than three significant digits, except prices.

[2]Lead recoverable after smelting and refining. Number in table 14 represents lead in concentrate.

[3]Withheld to avoid disclosing company proprietary data; included with "Primary lead, refined, lead content: Domestic ores and base bullion."

[4]Withheld to avoid disclosing company proprietary data; included with stocks at consumers and secondary smelters.

[5]Platts Metals Week.

[6]Primary metal production only; includes secondary metal production, where inseparable.

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TABLE 2
MINE PRODUCTION OF RECOVERABLE LEAD IN THE UNITED STATES, BY STATE[1]

(Metric tons, lead content)

State	2004[r]	2005
Alaska and Missouri	407,000	397,000
Other States[2]	23,400	29,500
Total	430,000	426,000

[r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Idaho, Montana, Nevada, and Washington.

TABLE 3
LEADING LEAD-PRODUCING MINES IN THE UNITED STATES IN 2005, IN ORDER OF OUTPUT[1]

Rank	Mine	County and State	Operator	Source of lead
1	Red Dog	Northwest Arctic, AK	Teck Cominco Alaska Inc.	Zinc-lead ore.
2	Buick	Iron, MO	Doe Run Resources Corp.	Lead ore.
3	Brushy Creek	Reynolds, MO	do.	Do.
4	Fletcher	do.	do.	Do.
5	Viburnum (#29 and #35)	Iron, MO	do.	Do.
6	Sweetwater	Reynolds, MO	do.	Do.
7	Greens Creek	Juneau, AK	Kennecott Greens Creek Mining Co.	Zinc ore.
8	Lucky Friday	Shoshone, ID	Hecla Mining Company	Silver ore.
9	Pend Oreille	Pend Oreille, WA	Teck Cominco American Inc.	Zinc-lead ore.
10	Montana Tunnels	Jefferson, MT	Apollo Gold Corp.	Gold ore.

[1]The mines on this list accounted for 100% of the U.S. mine production in 2005.

TABLE 4
LEAD RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES,
BY KIND OF SCRAP AND FORM OF RECOVERY[1]

(Metric tons, lead content, unless otherwise specified)

	2004	2005
Kind of scrap:		
New scrap:		
Lead-base	12,500	14,200
Copper-base	--	--
Tin-base	329	1,530
Total	12,900	15,800
Old scrap:		
Battery-lead	1,060,000 [r]	1,050,000
All other lead-base	49,100 [r]	80,500
Copper-base	--	--
Total	1,110,000 [r]	1,130,000
Grand total	1,130,000 [r]	1,140,000
Form of recovery:		
As soft lead	841,000 [r]	869,000
In antimonial lead	283,000 [r]	271,000
In other lead alloys	2,960	4,490
In copper-base alloys	--	--
Total:		
Quantity	1,130,000 [r]	1,140,000
Value[2] thousands	$1,370,000 [r]	$1,540,000

[r]Revised. NA Not available. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Value based on average quoted price of common lead.

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TABLE 5
U.S. CONSUMPTION OF LEAD, BY PRODUCT[1]

(Metric tons, lead content)

SIC[2] code	Product	2004	2005
	Metal products:		
3482	Ammunition, shot and bullets	61,500	61,300
	Bearing metals:		
35	Machinery except electrical	--	W
36	Electrical and electronic equipment	W	--
371	Motor vehicles and equipment[3]	W	W
37	Other transportation equipment	W	W
	Total	1,300	1,180
3351	Brass and bronze, billets and ingots	2,390	2,100
36	Cable covering, power and communication	(4)	(4)
15	Calking lead, building construction	(4)	(4)
	Casting metals:		
36	Electrical machinery and equipment	-- r	W
371	Motor vehicles and equipment	W	W
37	Other transportation equipment	W	W
3443	Nuclear radiation shielding	W	W
	Total	17,900	19,500
	Pipes, traps, other extruded products:		
15	Building construction	W	1,220
3443	Storage tanks, process vessels, etc.	(5)	(5)
	Total	W	1,220
	Sheet lead:		
15	Building construction	20,700 r	23,100
3443	Storage tanks, process vessels, etc.	(5)	(5)
3693	Medical radiation shielding	W	W
	Total	31,600 r	29,000
	Solder:		
15	Building construction	777	W
	Metal cans and shipping containers	W	W
367	Electronic components, accessories and other electrical equipment	6,380 r	7,720
371	Motor vehicles and equipment	W	W
	Total	7,440	8,370
	Storage batteries:		
3691	Storage battery grids, post, etc.	657,000	581,000
3691	Storage battery oxides	630,000	705,000
	Total storage batteries	1,290,000	1,290,000
371	Terne metal, motor vehicles and equipment	--	--
27	Type metal, printing and allied industries	--	(6)
34	Other metal products[7]	W	500
	Grand total	1,420,000	1,410,000
	Other oxides:		
285	Paint	W	W
32	Glass and ceramics products	W	W
28	Other pigments and chemicals	W	W
	Total	25,700	14,100
	Miscellaneous uses	33,900	32,900
	Grand total	1,480,000	1,460,000

rRevised. W Withheld to avoid disclosing company proprietary data; included in appropriate totals. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]SIC Standard Industrial Classification.

[3]Includes "Metal products: Storage batteries: Terne metal, motor vehicles and equipment."

[4]Included in "Metal products: Grand total."

[5]Included with "Metal products: Sheet lead: Building construction" to avoid disclosing company proprietary data.

[6]Included with "Metal products: Storage batteries: Other metal products" to avoid disclosing company proprietary data.

[7]Includes lead consumed in foil, collapsible tubes, annealing, galvanizing, plating, electrowinning, and fishing weights.

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TABLE 6
U.S. CONSUMPTION OF LEAD IN 2005, BY STATE[1, 2]

(Metric tons, lead content)

State	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
California and Washington	26,000	1,160	4,290	--	31,500
Illinois	6,490	30,000	(3)	--	36,400
Iowa, Michigan, Missouri	4,640	W	W	--	7,390
Ohio and Pennsylvania	95,300	117,000	34,600	670	247,000
Arkansas and Texas	60,000	18,200	7,080	--	85,300
Alabama, Georgia, and Oklahoma	27,000	W	W	--	52,800
Colorado, Indiana, Kansas, Kentucky, Minnesota, Nebraska, Tennessee, Wisconsin	263,000	55,200	52,300	630	371,000
Connecticut, Maryland, New Jersey, New York, North Carolina, South Carolina	20,100	14,100	6,390	--	40,700
Various States[4]	326,000	78,200	185,000	--	589,000
Total	829,000	309,000	323,000	1,300	1,460,000

W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes lead that went directly from scrap to fabricated products.

[3]Included in lead in antimonial lead to avoid disclosing company proprietary data.

[4]Includes companies that do not breakup their numbers by State.

TABLE 7
U.S. CONSUMPTION OF LEAD IN 2005, BY CLASS OF PRODUCT[1, 2]

(Metric tons, lead content)

Product	Soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
Metal products	51,400	69,100	8,460	W	129,000
Storage batteries	750,000	240,000	295,000	--	1,290,000
Other oxides	W	(3)	(3)	--	W
Miscellaneous	27,600	(3)	(3)	1,300	47,800
Total	829,000	309,000	323,000	1,300	1,460,000

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes lead that went directly from scrap to fabricated products.

[3]Withheld to avoid disclosing company proprietary data; included with "Total."

TABLE 8
STOCKS OF LEAD AT CONSUMERS AND SECONDARY SMELTERS
IN THE UNITED STATES, DECEMBER 31[1, 2]

(Metric tons, lead content)

Year	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
2004	34,400	11,500	W	W	59,000
2005	33,600	15,400	W	W	64,700

W Withheld to avoid disclosing company proprietary data; included in totals.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes stocks at primary refineries.

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TABLE 9

PRODUCTION AND SHIPMENTS OF LEAD PIGMENTS AND OXIDES IN THE UNITED STATES[1, 2]

(Metric tons and dollars)

	2004				2005			
	Production		Shipments		Production		Shipments	
Product	Gross weight	Lead content	Quantity (lead content)	Value[3]	Gross weight	Lead content	Quantity (lead content)	Value[3]
Litharge, red lead and white lead, dry	1,300	1,180	15,000	9,560,000	--	--	10,200	10,800,000
Leady oxide	663,000	630,000	NA	NA	742,000	705,000	NA	NA
Total	665,000 r	631,000 r	NA	NA	742,000	705,000	NA	NA

rRevised. NA Not available. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Excludes basic lead sulfate to avoid disclosing company proprietary data.

[3]At plant, exclusive of container.

TABLE 10

U.S. IMPORTS FOR CONSUMPTION OF LEAD PIGMENTS AND COMPOUNDS, BY KIND[1]

Kind	Quantity (metric tons, lead content)	Value (thousands)
2004:		
White lead carbonate	--	--
Red and orange lead	323	$549
Chrome yellow, molybdenum orange pigments, lead-zinc chromates	7,040	18,800
Litharge	983	878
Glass frits (undifferentiated)	24,900	27,800
Total	33,200	48,000
2005:		
White lead carbonate	--	--
Red and orange lead	355	543
Chrome yellow, molybdenum orange pigments, lead-zinc chromates	6,260	19,800
Litharge	967	1,390
Glass frits (undifferentiated)	24,900	33,700
Total	32,500	55,500

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 11
U.S. EXPORTS OF LEAD, BY COUNTRY[1]

Country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Ore and concentrates, lead content:				
Australia	157	$13	--	--
Belgium	14,800	13,900	11,500	$7,780
Bulgaria	2,890	1,990	5,760	3,880
Canada	31,500	17,200	145,000	54,400
China	98,000	56,000	115,000	75,300
India	--	--	219	134
Japan	63,500	31,700	47,800	20,200
Korea, South	52,800	22,600	31,200	10,000
Mexico	22,000	9,910	6,650	2,530
South Africa	56	17	--	--
Switzerland	59	75	27,100	16,100
Taiwan	5,770	3,970	--	--
Other	16	15	44	21
Total	292,000	157,000	390,000	190,000
Base bullion, lead content:				
Japan	58	757	91	1,180
Mexico	70	84	82	80
Other	--	--	25	28
Total	129	841	198	1,290
Unwrought lead and lead alloys, lead content:				
Australia	74	78	4	29
Belgium	8,640	6,700	494	612
Brazil	1,200	943	(2)	3
Canada	2,460	2,220	1,810	1,810
Colombia	6	31	37	471
Dominican Republic	132	201	1	3
France	30	296	18	103
Germany	47	112	26	36
Haiti	116	112	--	--
Hong Kong	--	--	158	87
India	1,550	1,270	12	28
Ireland	36	22	--	--
Israel	38	525	111	1,370
Italy	2,500	1,870	15	11
Japan	32	52	331	303
Korea, South	2,900	2,730	1,460	1,470
Malaysia	775	746	--	--
Mexico	24,800	22,000	39,700	37,400
Poland	304	334	3	57
Portugal	1,260	945	--	--
Saudi Arabia	(2)	9	116	71
Singapore	18	17	53	57
Spain	--	--	98	633
Taiwan	4,520	3,700	42	57
Tunisia	499	348	--	--
Turkey	1,110	868	--	--
United Kingdom	5,410	3,630	1,010	963
Other	42	221	39	106
Total	58,600	50,100	45,500	46,100

See footnotes at end of table.

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TABLE 11—Continued
U.S. EXPORTS OF LEAD, BY COUNTRY[1]

Country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Wrought lead and lead alloys, lead content:				
Armenia	--	--	97	$35
Belgium	146	$2,310	257	2,190
Brazil	130	259	149	1,090
Canada	3,750	7,310	1,660	4,570
China	1,270	2,660	1,050	3,170
Costa Rica	1,020	2,590	1,210	3,410
Dominican Republic	5	10	169	249
France	34	204	138	238
Germany	2,980	2,770	2,560	2,560
Hong Kong	1,640	2,610	1,250	2,810
India	211	261	409	592
Ireland	42	284	155	496
Israel	36	122	55	125
Italy	113	91	87	143
Japan	295	1,860	509	1,200
Korea, South	975	1,270	25	170
Malaysia	851	2,260	2,330	4,420
Mexico	4,140	6,360	3,110	6,260
Netherlands	86	631	107	382
Philippines	1,910	2,050	2,720	3,000
Saudi Arabia	32	108	20	58
Singapore	405	444	76	115
Sweden	8	15	26	71
Switzerland	79	86	121	145
Taiwan	2,080	1,990	51	1,090
United Arab Emirates	40	95	21	30
United Kingdom	852	1,280	436	849
Venezuela	93	78	68	185
Other	573	2,290	153	1,170
Total	23,800	42,300	19,000	40,800
Scrap, gross weight:				
Belgium	114	189	64	110
Canada	44,400	8,500	53,400	12,400
China	174	118	2,120	2,040
Dominican Republic	674	805	20	35
El Salvador	--	--	26	34
Finland	--	--	351	651
Guatemala	87	85	11	29
Honduras	--	--	82	175
Hong Kong	46	31	162	66
India	1,280	1,030	3,560	2,130
Korea, South	8,800	3,140	6,820	3,100
Mexico	268	195	32	55
Pakistan	--	--	166	48
Sri Lanka	39	17	138	60
United Kingdom	--	--	114	246
Vietnam	--	--	186	66
Other	428	641	75	394
Total	56,300	14,800	67,300	21,600

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF LEAD, BY COUNTRY[1]

Country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Pigs and bars, lead content:				
Argentina	133	$115	113	$120
Australia	13,700	10,700	39,600	38,900
Belgium	26	178	51	334
Canada	166,000	149,000	190,000	199,000
China	2	4	22,700	22,500
Colombia	80	58	302	270
Germany	309	1,410	107	488
Japan	--	--	228	229
Mexico	8,810	5,110	15,200	12,300
Panama	375	235	--	--
Peru	7,270	7,220	23,900	24,400
Poland	126	107	--	--
United Kingdom	--	--	5,460	4,830
Venezuela	367	318	--	--
Other	29	64 r	25	68
Total	197,000	175,000	298,000	303,000
Reclaimed scrap, including ash and residues, lead content:				
Canada	612	446	1,070	1,050
Chile	--	--	32	27
Colombia	3,280	2,290	1,060	897
Guatemala	--	--	110	116
Mexico	525	669	1,020	711
Russia	311	75	22	20
Tunisia	--	--	28	59
Venezuela	40	30	--	--
Other	14	7	--	--
Total	4,780	3,510	3,340	2,880
Wrought lead, all forms, including wire and powders, gross weight:				
Argentina	376	409	1,060	1,370
Australia	--	--	28	105
Austria	--	--	215	889
Canada	4,530	8,010	5,190	11,000
Chile	1,150	1,740	--	--
China	922	3,380	792	2,950
Colombia	120	76	3	3
El Salvador	--	--	120	185
France	50	187	78	242
Germany	843	3,550	982	3,980
Japan	21	182	7	163
Mexico	1,110	937	1,970	2,040
Netherlands	321	1,570	334	1,780
New Zealand	33	364	66	675
Peru	6	3	79	143
Russia	155	852	59	352
Taiwan	182	675	136	529
Turkey	--	--	40	65
United Kingdom	1,050	2,280	645	1,360
Other	104	960	92	994
Total	11,000	25,200	11,900	28,900

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 13

LEAD: WORLD MINE PRODUCTION OF LEAD IN CONCENTRATE, BY COUNTRY[1, 2]

(Metric tons, lead content)

Country[3]	2001	2002	2003	2004	2005
Algeria	891 r	1,105	--	--	--
Argentina	12,334	12,011	12,079	9,551	10,000
Australia	714,000	683,000 r	690,000 r	678,000 r	776,000
Bolivia	8,857	9,893	9,740	10,267 r	10,700
Bosnia and Herzegovina e	200	200	200	200	200
Brazil	10,725	9,253	10,652	14,734 r	15,000 p
Bulgaria	18,500	21,800	17,000 e	13,000 e	13,000 e
Burma e	900	900	500	500	500
Canada	153,932	101,330	92,934 r	71,122 r	72,500 p
Chile	1,193	2,895 r	1,697 r	2,286 r	878
China e	676,000	641,000	955,000	998,000 r	1,000,000
Colombia e	220	220	220	220	220
Ecuador e	200	200	200	220	220
Georgia e	200	400	400	400	400
Greece e	27,700	29,300	2,000	--	1,500
Honduras	6,750	8,128	9,014 r	8,877 r	10,488
India	32,000	34,000	44,000	51,000 e	58,000 p
Iran e, 4	19,000 r	19,000 r	20,000 r	22,000 r	22,000
Ireland e	44,500	32,000	50,000	65,000	63,800
Italy e	1,000 r	500 r	500 r	500 r	500
Japan	4,997	5,723	5,660	5,512 r	3,437
Kazakhstan e	37,700 5	40,000	44,000	44,000	44,000
Korea, North e	9,000 r	10,000 r	20,000 r	20,000 r	20,000
Korea, Republic of	988	28	--	40 r	--
Macedonia	9,700	3,500	5,000	-- e	-- e
Mexico	139,000	138,707	139,348	118,484 r	130,000 e
Morocco	76,747	62,400 r	38,600 r	31,300 r, e	31,000 e
Namibia	12,088 r	13,809 r	18,782 r	14,338 r	14,320
Peru	289,546	297,704	307,755	306,211	319,345
Poland	52,600	56,600	42,000	40,000 e	48,000 e
Romania	19,676	15,136	18,102	18,000 e	18,000 e
Russia e	12,300	19,000	24,000	23,000 r	36,000
Saudi Arabia e	60	60	60	30	30
Serbia and Montenegro	7,500	--	400	-- e	-- e
South Africa	50,771	49,444	39,941	37,485	42,159 p
Spain	36,000	6,000	2,000 e	-- e	2,000 e
Sweden	85,975	44,000 r	51,000 e	55,000	61,000
Tajikistan e	800	800	800	800	800
Thailand	500	3,200	--	-- e	--
Tunisia	6,820	5,081	5,000 e	5,500 r, e	8,800 e
Turkey	17,923	17,352	14,000 e	12,000 e	12,000 e
United Kingdom e	1,000	1,000	--	--	--
United States	450,256 r	440,086 r	448,661 r	430,006 r	426,350
Vietnam e	900 r	1,100 r	1,100 r	1,100 r	1,200
Total	3,050,000 r	2,840,000 r	3,140,000	3,110,000	3,270,000

eEstimated. pPreliminary. rRevised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 7, 2006.

[3]In addition to the countries listed, lead is also produced in Nigeria, but information is inadequate to formulate reliable estimates of output levels.

[4]Year beginning March 21 of that stated.

[5]Reported figure.

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TABLE 14

LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Algeria:[e]					
Primary	-- [r]	-- [r]	-- [r]	--	--
Secondary	6,100 [r]	6,000 [r]	6,000 [r]	5,000	5,000
Total	6,100 [r]	6,000 [r]	6,000 [r]	5,000	5,000
Argentina:					
Primary	9,473	10,567	11,011	9,500 [r, e]	10,000
Secondary	25,960	33,000	30,300	39,600 [r, e]	39,000
Total	35,433	43,567	41,311	49,100 [r, e]	49,000
Australia:					
Primary	270,000	268,400 [r]	267,700 [r]	239,000 [r]	229,300 [4]
Secondary	33,000	33,600 [r]	39,300 [r]	34,000 [r]	38,700 [4]
Total	303,000	302,000 [r]	307,000 [r]	273,000	268,000 [4]
Austria, secondary[e]	22,000	21,000	18,000	20,000	20,000
Belgium:[e]					
Primary[5]	76,000	68,000	45,000	43,000	63,000
Secondary	20,000	20,000	20,000	20,000	20,000
Total	96,000	88,000	65,000	63,000	83,000
Bolivia	106 [r]	100 [r, e, 6]	100 [r, e, 6]	539 [r]	540
Brazil, secondary	50,000 [7]	50,000 [e, 7]	50,000 [e]	52,000 [r]	52,000 [p]
Bulgaria:[e]					
Primary	75,000	57,000	60,000	55,000 [r]	65,000
Secondary	13,600	9,000	9,000	10,000 [r]	15,000
Total	88,600	66,000	69,000	65,000 [r]	80,000
Burma, primary	1,105 [r]	425 [r]	888	289 [r]	300
Canada:					
Primary	127,007	136,896 [r]	118,506	131,015	132,000 [p]
Secondary	103,921	114,664 [r]	104,927 [r]	110,382	112,000 [p]
Total	230,928	251,560 [r]	223,433 [r]	241,397	244,000 [p]
China:[e]					
Primary	984,000	1,100,000	1,290,000	1,500,000	1,870,000
Secondary	211,000	230,000	290,000	430,000 [r]	520,000
Total	1,200,000	1,330,000	1,580,000	1,930,000 [r]	2,390,000
Colombia, secondary[e]	12,000	12,000	12,000	12,000	12,000
Czech Republic, secondary[e]	15,000	29,000 [r]	26,000 [r]	25,000 [r]	26,000
El Salvador, secondary	7,000	8,000	8,000	10,000	10,000
Estonia, secondary	--	--	--	3,000	7,000
France:[e]					
Primary	96,000	76,000	14,000	--	--
Secondary	142,000	128,000	80,000	104,000	105,000
Total	238,000	204,000	94,000	104,000	105,000
Germany:					
Primary	155,862 [r]	141,202 [r]	132,155 [r]	115,869 [r]	116,000
Secondary	217,500 [r]	238,700	222,400 [r]	243,304 [r]	243,000
Total	373,362 [r]	379,902 [r]	354,555 [r]	359,173 [r]	359,000
Greece, secondary	5,000	5,000	4,000	4,000	4,000
India:[e]					
Primary	74,400	51,500 [r]	51,200 [r]	33,700 [r]	38,900 [p]
Secondary	22,000	26,500 [r]	26,300 [r]	15,300 [r]	20,100 [p]
Total	96,400	78,000 [r]	77,500 [r]	49,000 [r]	59,000 [p]
Indonesia, secondary	18,000	17,000	18,000	20,000	18,000
Iran:[e]					
Primary	12,000	12,000	11,342 [r, 4]	17,857 [r, 4]	18,000
Secondary	38,000	39,000 [r]	47,000 [r]	50,000 [r]	50,000
Total	50,000	51,000 [r]	58,342 [r, 4]	67,857 [r, 4]	68,000

See footnotes at end of table.

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TABLE 14—Continued

LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Ireland, secondary[e]	13,000	7,000	9,000	21,000	20,000
Israel, secondary	20,000	22,000	25,000	27,000	27,000
Italy:[e]					
Primary	82,000	75,000	48,000	45,000	45,000
Secondary	121,000	130,000	166,000	165,000	161,000
Total	203,000	205,000	214,000	210,000	206,000
Japan:					
Primary	127,358	107,744	105,460 r	94,272 r	106,638 [4]
Secondary	175,088	178,016	189,831	188,603 r	167,980 [4]
Total	302,446	285,760	295,291 r	282,875 r	274,618 [4]
Kazakhstan, primary and secondary	158,700	161,800	133,200	157,000 e	131,316 [4]
Kenya, secondary	1,000	1,000	1,000	1,000	1,000
Korea, North, primary and secondary[e]	7,000 r	6,000 r	7,000 r	9,000 r	9,000
Korea, Republic of:					
Primary	161,000	178,722	169,297 r	173,609 r	175,000
Secondary[e]	10,000	63,900	60,000	60,000 [4]	50,000
Total	171,000	242,622	229,297 r	233,609 r	225,000
Macedonia:[e]					
Primary	19,000	19,000	6,000	--	--
Secondary	1,000	1,000	400	300 r	300
Total	20,000	20,000	6,400	300 r	300
Malaysia, secondary[e, 8]	42,000	40,000	57,000	54,000	71,000
Mexico:					
Primary[9]	143,523	128,241	137,482	137,090 r	150,000
Secondary[e]	110,000	110,000	110,000	110,000	110,000
Total	253,523	238,241	247,482	247,090 r	260,000
Morocco:					
Primary	58,178	71,840	61,473	35,000 r	35,000
Secondary[e]	3,000	3,000	3,000	3,000 r	4,000 [4]
Total	61,178	74,840	64,473	38,000 r	39,000
Netherlands, secondary[e]	24,000	25,000	17,000	17,000	20,000
New Zealand, secondary[e]	10,000	9,000 r	8,000 r	8,000 r, 4	7,000 [4]
Nigeria, secondary[e]	5,000	5,000	5,000	5,000	5,000
Pakistan, secondary[e]	3,000	3,000 r	3,000	3,000	3,000
Peru, primary	121,181	119,588	112,289	118,570	122,079 [4]
Philippines, secondary[e]	24,000	26,000 r	27,000	29,000	29,000 [4]
Poland:[e]					
Primary	30,000 r	30,000	28,000	25,000 r	30,000
Secondary	20,000	35,800	40,000	40,000	40,000
Total	50,000 r	65,800	68,000	65,000 r	70,000
Portugal, secondary[e]	6,000	4,000	4,000	4,000	4,000
Romania:[e]					
Primary	24,000	26,000	23,100	25,000	25,000
Secondary	3,000	3,000	5,000	3,000	3,000
Total	27,000	29,000	28,100	28,000	28,000
Russia, primary and secondary[e]	67,500	60,350 [4]	66,000	70,000 r	66,000
Saudi Arabia, secondary	16,000	17,000	25,000	32,000	36,000
Serbia and Montenegro, primary[e]	--	170	--	--	--
Slovenia, secondary[e]	15,000	15,000	15,000	15,000	15,000
South Africa, secondary	55,000	61,000	64,900	64,100 r	65,000
Spain, secondary[e]	98,000	116,000	102,000	105,000	106,000

See footnotes at end of table.

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TABLE 14—Continued

LEAD: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Sweden:[e]					
Primary	31,322 [4]	28,000 [r]	24,200	30,200 [r, 4]	27,400
Secondary	44,056 [4]	37,000 [r]	52,000	52,000 [r, 4]	45,600
Total	75,378 [4]	65,000 [r]	76,200	82,200 [r, 4]	73,000
Switzerland, secondary[e]	9,000	9,000	8,000	9,000	9,000
Taiwan, secondary	62,000	55,000	56,000	56,000	55,000 [p]
Thailand:					
Primary	-- [r]	-- [r]	-- [r]	-- [r]	--
Secondary	30,000 [r]	42,900 [r]	45,300 [r]	57,500 [r]	61,000
Total	30,000 [r]	42,900 [r]	45,300 [r]	57,500 [r]	61,000
Trinidad and Tobago, secondary[e]	1,600	1,600	1,000 [r]	1,000 [r]	1,000
Turkey:[e]					
Primary	-- [r]	-- [r]	-- [r]	-- [r]	--
Secondary	4,000 [r]	6,000 [r]	6,000 [r]	6,000 [r]	6,000
Total	4,000 [r]	6,000	6,000	6,000	6,000
Ukraine, secondary[e]	12,000	12,000	7,000	7,000	6,000
United Arab Emirates, secondary[e]	2,000	2,000	2,000	2,000	2,000
United Kingdom:[e]					
Primary	203,000	205,000	162,000	123,000	120,000
Secondary	163,000	165,000	158,000	120,000	120,000
Total	366,000	370,000	320,000	243,000	240,000
United States:					
Primary	290,000	262,000	245,000	148,000	143,000
Secondary	1,100,000	1,120,000	1,140,000	1,110,000	1,140,000
Total	1,390,000	1,380,000	1,380,000	1,260,000	1,280,000
Venezuela, secondary[e]	30,000	30,000	30,000	30,000	30,000
Zambia, secondary[e]	1,000	1,000	1,000	1,000	1,000
Grand total:	6,600,000 [r]	6,780,000 [r]	6,780,000 [r]	6,950,000 [r]	7,470,000
Of which					
Primary	3,170,000 [r]	3,170,000 [r]	3,120,000 [r]	3,100,000 [r]	3,520,000
Secondary	3,200,000 [r]	3,370,000 [r]	3,450,000 [r]	3,620,000 [r]	3,740,000
Undifferentiated	233,000 [r]	228,000 [r]	206,000 [r]	237,000 [r]	207,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 7, 2006. Data included represent the total output of refined lead by each country, whether derived from ores and concentrates (primary) or scrap (secondary), and include the lead content of antimonial lead but exclude, to the extent possible, simple remelting of scrap.

[3]In addition to the countries listed, Egypt and Iraq produced secondary lead, but output is not officially reported; available general information is inadequate for the formulation of reliable estimates of output levels.

[4]Reported figure.

[5]Derived by calculating reported total lead output plus exports of lead bullion minus imports of lead bullion.

[6]For 2002 and 2003, the only production of refined lead that was reported consisted of small amounts recovered as a byproduct at Empresa Metalúrgica de Vinto.

[7]Source: Lead and Zinc Statistics, Monthly Bulletin of the International Lead and Zinc Study Group, v. 42, no. 6, June 2002.

[8]Metal Reclamation Industries' secondary lead smelter is receiving some primary mine concentrates from the Magellan Mine (Australia). The ore minerals are lead oxides and can be smelted at a secondary smelter.

[9]Includes lead content in antimonial lead.

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LIME

By M. Michael Miller

Domestic survey data and tables were prepared by Lisa D. Miller, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

In 2005, U.S. production of lime increased slightly, but the rounded grand total was essentially unchanged at 20.0 million metric tons (Mt) (22.0 million short tons) compared with 2004 (table 1). The value of production increased by $130 million to $1.50 billion as a result of overall price increases of nearly 9% in 2005. Decreased consumption of quicklime by the steel industry was balanced by increased consumption of hydrated lime in construction markets.

The term lime as used throughout this chapter refers primarily to six chemicals produced by the calcination of high-purity calcitic or dolomitic limestone followed by hydration where necessary. There are two high-calcium forms—high-calcium quicklime (calcium oxide, CaO) and high-calcium hydrated lime [calcium hydroxide, $Ca(OH)_2$]. There are four dolomitic forms—dolomitic quicklime ($CaO \cdot MgO$), dolomitic hydrate type N [$Ca(OH)_2 \cdot MgO$], dolomitic hydrate type S [$Ca(OH)_2 \cdot Mg(OH)_2$], and refractory dead-burned dolomite ($CaO \cdot MgO$). Lime also can be produced from a variety of calcareous materials, such as aragonite, chalk, coral, marble, and shell. It also is regenerated (produced as a byproduct) by paper mills, carbide plants, and water-treatment plants. Regenerated lime, however, is beyond the scope of this report.

Production

Domestic production data for lime were derived by the U.S. Geological Survey (USGS) from a voluntary survey of U.S. operations. The survey was sent to primary producers of quicklime and hydrate, but was not sent to independent hydrators that purchase quicklime for hydration in order to avoid double counting. Quantity data were collected for 28 specific and general end uses, and value data were collected by type of lime, such as high-calcium or dolomitic. Because value data were not collected by end use, value data listed in table 4 were determined by calculating the average value per metric ton of quicklime sold or used for each respondent and then multiplying it by the quantity of quicklime that the respondent reported sold or used for each end use. The table lists the total quantity sold or used for an end use and the total value of the quicklime and hydrate sold or used for that end use calculated as described above. The same methodology was used to calculate the value of hydrate sold and used listed in table 5.

In 2005, of the 95 operations to which an annual survey form was sent, responses were received from 81 plants, representing 95% of the total sold or used by producers. Production data for the 14 nonrespondents were estimated based on prior-year production figures and other information.

Lime is a basic chemical that was produced as quicklime or hydrate at in 35 States and Puerto Rico (table 2). At the end of 2005, quicklime was being produced at 85 lime plants operating kilns, which included 38 plants with collocated hydrating plants. Hydrated lime also was produced at 12 standalone hydrating facilities, including 2 plants where the kilns had been shut down and hydrate was manufactured from quicklime produced offsite. These numbers do not necessarily agree with the number of plants reported in tables 1 and 2 because for data collection purposes some company operations (owing to their physical proximity to one another) have been combined at the respondent's request. In a few States with no quicklime production, hydrating plants used quicklime shipped from other States. There was also a small number of slurry plants where lime was converted to liquid form by the addition of water prior to sale; this is sometimes called milk-of-lime. States with production exceeding 2 Mt were, in descending order, Missouri, Kentucky, and Alabama; States with production between 1 and 2 Mt were, in descending order, Ohio, Texas, Nevada, and Pennsylvania.

Total lime sold or used by domestic producers in 2005 was 20 Mt, about the same as in 2004. Production included the commercial sale or captive consumption of quicklime, hydrated lime, and dead-burned refractory dolomite. The production of high-calcium and dolomitic quicklime was essentially unchanged, but production of high-calcium hydrate increased by 3.8% and dolomitic hydrate increased by 12.6%. Commercial sales increased by about 114,000 metric tons (t) (126,000 short tons) to about 18.6 Mt (20.5 million short tons), and captive consumption decreased by 27,000 t (30,000 short tons) to 1.49 Mt (1.64 million short tons).

In late 2005, National Lime & Stone Co. announced that it was closing its Carey lime plant in Ohio. The lime operation was a small part of the company's business and had operated at a loss 4 of the past 6 years. A steep rise in energy costs plus increasingly stringent environmental regulations also contributed to the decision to close the plant (Pit & Quarry, 2005§[1]).

Carmeuse Lime announced plans to upgrade production and distribution of lime products at several of its lime operations. The plans included the restart of a 136,000-metric-ton-per-year (t/yr) (150,000-short-ton-per-year) kiln at its Black River, KY, plant. Additionally, Carmeuse will construct a new hydrator plant and distribution terminal in South Carolina and upgrade existing hydrator plants in Alabama, Illinois, Louisiana, Pennsylvania, and Ontario, Canada (Carmeuse Lime, 2005a). Carmeuse also announced the closure of its Hanover, PA, lime plant. The plant had a capacity of about 180,000 t/yr from three calcimatic kilns that burned waste oil for fuel. The decision to close the plant was based on the age of the equipment, high operating costs, and the fact that recently completed capacity improvements at other Carmeuse plants more than made up

[1]References that include a section mark (§) are found in the Internet References Cited section.

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for the lost production. The site will remain operational as a distribution terminal working in conjunction with the company's Annville, PA, plant and other plants in the company network (Carmeuse Lime, 2005b; Industrial Minerals, 2005).

Oglebay Norton Co. (parent company of Global Stone Corp.) began what turned out to be a very busy year by emerging from Chapter 11 bankruptcy protection on January 31, pursuant to a plan of reorganization approved by the U.S. Bankruptcy Court for the District of Delaware on November 17, 2004. Effective May 1, 2005, Oglebay Norton unified all its limestone and lime operations under the name O-N Minerals. The new name applies to all the company's Michigan Limestone Operations and Global Stone locations. In October, Oglebay Norton announced that its wholly owned subsidiary O-N Minerals had entered into an agreement with Western Lime Corp. (West Bend, WI), whereby Western Lime will lease land at O-N Minerals' Port Inland limestone operation on Michigan's Upper Peninsula and construct a lime plant. O-N Minerals will supply stone to the lime plant, which will operate a single lime kiln with a capacity of about 180,000 t/yr. The lime plant is expected to be operational in 2007 and will be Western Lime's third lime plant. Lastly, Oglebay Norton sold its O-N Minerals (St. Clair) Co. lime and limestone operation in Marble City, OK, to United States Lime & Minerals, Inc. The operation was formerly known as Global Stone St. Clair, Inc. (Oglebay Norton Co., 2005§).

In addition to the acquisition of the St. Clair operation mentioned above, U.S. Lime & Minerals, Inc. also entered into the initial contract for the construction of a third kiln at its Arkansas Lime Co. plant in Batesville, AR. The contract will include enhancements to crushing and stone handling facilities, and construction of additional product silos and load outs. The new kiln will increase plant capacity by about 50%. The project was expected to be completed by summer 2006 (United States Lime & Minerals, Inc., 2005§).

Graymont (PA) Inc. started up its new 1,090-metric-ton-per-day (t/d) preheater rotary kiln (designated kiln #6) at its Pleasant Gap, PA, plant in October. A new hydrating plant, additional lime storage, and new loading facilities were also part of the project. Graymont, which has three lime plants in Centre County, PA, is in the process of consolidating all its Pennsylvania lime production at the Pleasant Gap plant. The company ceased production at its Con Lime plant in 2001 and expected to end lime production at its Bellefonte plant by summer 2006. To replace capacity lost by closing these plants, in addition to kiln #6, Graymont has future plans to construct a 950-t/d rotary kiln at Pleasant Gap that will be designated kiln #7 (Graymont Ltd., 2005§).

Mississippi Lime Co. commissioned its second RCE vertical shaft kiln in August. The RCE lime kiln is manufactured by RCE Industrieofenbau Engineering GmbH of Austria (a subsidiary of Swiss kiln company Maerz Ofenbau AG). The kiln is a high efficiency single shaft kiln designed to produce lime with low levels of impurities, such as sulfur. This is the second of three identical gas-fired shaft kilns being constructed by Mississippi Lime; the first kiln went into operation in 2002 (Maerz Ofenbau AG, 2005§).

Hurricanes Katrina and Rita had minimal impact on U.S. lime operations. The only lime plant that was in the immediate New Orleans, LA, area (owned by USG Corp.) closed in 2004. There were some disruptions in normal sales activities at lime plants or hydrating plants in the region, but the facilities were not directly affected.

At yearend, the top 10 companies, in descending order of production, were Carmeuse Lime, Chemical Lime Co., Graymont Ltd., Mississippi Lime, O-N Minerals, United States Lime & Minerals, Martin Marietta Magnesia Specialties LLC, Western Lime Corp., Southern Lime Co., and Cutler-Magner Corp. These companies operated 44 lime plants and 8 separate hydrating plants and accounted for nearly 90% of the combined commercial sales of quicklime and hydrated lime and 84% of total lime production.

Environment

The U.S. Environmental Protection Agency (EPA) announced in December that it was proposing revisions to its national air quality standards for fine particulate matter and some coarse particles. When breathed, these particles can accumulate in the respiratory system and are associated with numerous health effects. The proposed revisions addressed two categories of particulate matter—fine particles ($PM_{2.5}$), which are particles 2.5 micrometers (μm) in diameter and smaller; and inhalable coarse particles ($PM_{10-2.5}$), which are particles between 2.5 and 10 μm. Under the proposed rule, the current annual standard for $PM_{2.5}$ of 15 micrograms per cubic meter (μg/m³) would be retained, and the daily limit would be reduced to 35 μg/m³ from 65 μg/m³. For $PM_{10-2.5}$, the EPA is proposing to reduce the current 24-hour standard to 70 μg/m³ from 150 μg/m³. The standard would apply to airborne mixes of coarse particles that come from such sources as high-density traffic on paved roads and industry. The proposed standard would not apply to mixes of coarse particles that do not pose much risk to public health, such as windblown dust and soils and agricultural and mining sources (U.S. Environmental Protection Agency, 2006§).

Lime plants tend to be inherently dusty operations; more stringent regulation of particulate matter emissions would increase costs by increasing monitoring and possibly require installation of additional control technologies. This would be the case especially if the plant is located in a nonattainment area, which is an area that fails to meet emission standards. When a nonattainment designation takes effect in an area, the State and local governments have 3 years to develop implementation plans to meet the EPA standards by reducing air pollutant emissions that contribute to fine particle concentrations.

Consumption

The breakdown of consumption by general end-use sectors was as follows: 36% for metallurgical uses, 28% for environmental uses, 21% for chemical and industrial uses, 14% for construction uses, and 1% for refractory dolomite (table 4). Consumption increased in the construction and the chemical and industrial sectors by about 10% and 2%, respectively. Consumption decreased by about 2% in both the environmental and metallurgical sectors.

Commercial sales accounted for about 93% of total lime consumption. Captive lime accounted for about 7% of

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consumption and was used mainly in the production of steel in basic oxygen furnaces, sugar refining, magnesia production, and refractories. Almost all data on captive lime consumption, excluding the sugar industry, are withheld to avoid disclosing company proprietary information. As a result, table 4 lists the total quantity and value of lime by end use. End uses with captive consumption are listed in footnote 4 of the table.

In steel refining, quicklime is used as a flux to remove impurities, such as phosphorus, silica, and sulfur. The steel industry accounted for 30% of all lime consumed in the United States. In 2005, estimated raw steel production in the United States decreased by nearly 6% compared with that of 2004. This decrease was reflected in the consumption of lime for steel and iron uses, which decreased by more than 3% to 5.98 Mt (6.59 million short tons).

In nonferrous metallurgy, lime is used in the beneficiation of copper ores to neutralize the acidic effects of pyrite and other iron sulfides and to maintain the proper pH in the flotation process. Lime is used to process alumina and magnesia, to extract uranium from gold slimes, to recover nickel by precipitation, and to control the pH of the sodium cyanide solution used to leach gold and silver from the ore. Such leaching processes are called dump leaching when large pieces of ore are involved, heap leaching when small pieces of ore are involved, and carbon-in-pulp cyanidation when the ore is leached in agitation tanks. Dump and heap leaching involve crushing the ore, mixing it with lime for pH control and agglomeration, and stacking the ore in heaps for treatment with cyanide solution. Lime is used to maintain the pH of the cyanide solution at a level between 10 and 11 to maximize the recovery of precious metals and to prevent the creation of hydrogen cyanide. Lime consumed for these various uses is included in table 4 under the category "Nonferrous metallurgy." Lime usage in nonferrous metallurgy (aluminum and bauxite processing, concentration of copper and gold ores, and unspecified nonferrous uses) increased by 4% in 2005. The increase was primarily in the ore concentration sector as domestic production of copper concentrates and gold each increased by about 2% in 2005 (Edelstein, 2006§; George, 2006§).

Environmental remediation uses of lime in mining include treatment of the tailings that result from the recovery of precious metals, such as gold and silver. These tailings may contain elevated levels of cyanides, and lime is used to recover cyanides in such treatment processes as alkaline chlorination, Caro's acid (H_2SO_5), Cyanisorb™, and sulfur dioxide/air.

Other environmental uses include the softening and clarification of municipal potable water and neutralization of acid-mine drainage and industrial discharges. In sewage treatment, the traditional role of lime is to control pH in the sludge digester, which removes dissolved and suspended solids that contain phosphates and nitrogen compounds. Lime also aids in clarification and in destroying harmful bacteria. More recently, the leading use in sewage treatment has been to stabilize the resulting sewage sludge. Sewage sludge stabilization, also called biosolids stabilization, reduces odors, pathogens, and putrescibility of the solids. Lime stabilization involves mixing quicklime with the sludge to raise the temperature and pH of the sludge to minimum levels for a specified period of time. Lime consumption for all sludge treatment decreased by about 7% compared with that of 2004.

In flue gas desulfurization (FGD) systems serving coal-fired powerplants, incinerators, and industrial plants, lime is injected into the flue gas to remove acidic gases, particularly sulfur dioxide (SO_2) and hydrochloric acid (HCl). It also may be used to stabilize the resulting sludge before disposal. Many FGD systems at powerplants are now designed to produce byproduct gypsum from the SO_2 emissions suitable for use in manufacturing gypsum wallboard. Hydrated lime may be used in another FGD-related market—to control sulfur trioxide (SO_3) emissions from selective catalytic reduction (SCR) systems installed at powerplants to control emissions of nitrogen oxides (NO_x). In 2005, consumption in the utility powerplant FGD market decreased by 40,000 t, while consumption in the incinerator and industrial boiler sectors were essentially unchanged.

Lime is used by the pulp and paper industry in the basic Kraft pulping process where wood chips and an aqueous solution (called liquor) of sodium hydroxide and sodium sulfide are heated in a digester. The cooked wood chips (pulp) are discharged under pressure along with the spent liquor. The pulp is screened, washed, and sent directly to the paper machine or for bleaching. Lime is sometimes used to produce calcium hypochlorite bleach for bleaching the paper pulp. The spent liquor is processed through a recovery furnace where dissolved organics are burned to recover waste heat, sodium sulfide, and sodium carbonate. The recovered sodium sulfide and sodium carbonate are diluted with water and then treated with slaked lime to recausticize the sodium carbonate into sodium hydroxide (caustic soda) for reuse. The byproduct calcium carbonate is recalcined in a lime kiln to recover lime for reuse. The paper industry also uses lime as a coagulant aid in the clarification of plant process water.

According to the American Forest & Paper Association's annual survey of paper, paperboard, and pulp capacity, U.S. paper and paperboard production capacity declined in 2005, extending a trend that began in 2001 (Paper Age, 2006§). Lime consumption for pulp and paper production decreased by nearly 4% in 2005.

Lime is used to make precipitated calcium carbonate (PCC), a specialty filler used in premium-quality coated and uncoated papers, paint, and plastics. The most common PCC production process used in the United States is the carbonation process. Carbon dioxide (CO_2) is bubbled through milk-of-lime to form a precipitate of calcium carbonate and water. The reaction conditions determine the size and shape of the resulting PCC crystals. Lime use for PCC production decreased by about 5% compared with 2004.

Lime is used, generally in conjunction with soda ash, for softening plant process water. This precipitation process removes bivalent soluble calcium and magnesium cations (and to a lesser extent ferrous iron, manganese, strontium, and zinc) that contribute to the hardness of water. This process also reduces carbonate alkalinity and total dissolved solids.

The chemical industry uses lime in the manufacture of alkalis. Quicklime is combined with coke to produce calcium carbide, which is used to make acetylene and calcium cyanide. Lime is

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used to make calcium hypochlorite, citric acid, petrochemicals, and other chemicals.

In sugar refining, milk-of-lime is used to raise the pH of the product stream, precipitating colloidal impurities. The lime itself is then removed by reaction with CO_2 to precipitate calcium carbonate. The CO_2 is obtained as a byproduct of lime production.

In road paving, hydrated lime is used in hot-mix asphalt to act as an antistripping agent. Stripping is generally defined as a loss of adhesion between the aggregate surface and the asphalt cement binder in the presence of moisture. Lime also is used in cold in-place recycling for the rehabilitation of distressed asphalt pavements. Existing asphalt pavement is pulverized by using a milling machine, and a hot lime slurry is added along with asphalt emulsion. The cold recycled mix is placed and compacted by conventional paving equipment, which produces a smooth base course for the new asphalt surface. In 2005, sales of lime for use in asphalt increased by nearly 8% compared with the revised figure for 2004.

In construction, hydrated lime and quicklime are used to stabilize fine-grained soils in place of materials that are employed as subbases, such as hydraulic clay fills or otherwise poor-quality clay and silty materials obtained from cuts or borrow pits. Lime also is used in base stabilization, which includes upgrading the strength and consistency properties of aggregates that may be judged unusable or marginal without stabilization. Common applications for lime stabilization included the construction of airfields, building foundations, earthen dams, parking areas, and roads. Lime sales for soil stabilization increased by 8% compared with the revised figure for 2004. The total of 1.73 Mt set a new record high for the market, surpassing the previous high (achieved in 2003) by 90,000 t.

In the traditional building sector, quicklime is used to make calcium silicate building products, such as autoclaved aerated concrete and sand-lime brick. Autoclaved aerated concrete has the advantage of producing building materials that can be cut, drilled, and nailed like wood but otherwise possess qualities similar to regular concrete products.

Hydrated lime is used in the traditional building sector in mortars, plaster, and stucco. Standard cement mortars that include lime exhibit superior workability balanced with appropriate compressive strength, as well as low water permeability and superior bond strength. Lime is a major constituent in exterior and interior stuccos and plasters, enhancing the strength, durability, and workability of these finishes. A small amount of hydrated lime also is used in the renovation of old structures built with lime-based mortars, which was standard before the development of portland-cement-based mortars. Modern portland-cement-based mortars are incompatible with old lime mortars. Hydrated lime also is used to make synthetic hydraulic lime, which is produced by blending powdered hydrated lime with pulverized pozzolanic or hydraulic materials.

According to the U.S. Census Bureau, the annual value of construction put in place increased by 9% in 2005 compared with that of 2004. The values of residential and nonresidential construction increased by 11% and 6%, respectively (U.S. Census Bureau, 2006§). The strong construction markets resulted in an 8% increase in the amount of hydrated lime sold for the traditional building markets. The bulk (nearly 80%) of lime sold for building uses is produced at five plants located in Nevada, Ohio, Utah, and Wisconsin.

Dead-burned dolomite, also called refractory lime, is used as a component in tar-bonded refractory brick or monolithics manufactured for use in basic oxygen furnaces. Refractory brick also is used in the lining of many treatment and casting ladles, in argon oxygen decarburization and vacuum oxygen decarburization converters, in electric arc furnaces, and in continuous steel casting. Although the actual numbers are rounded to one significant figure to avoid disclosing company proprietary data, the production of dead-burned dolomite sold and used was essentially unchanged in 2004. LWB Refractories Co. (York, PA) and Carmeuse Lime (Millersville, OH) were the only significant producers. Hydrated lime is used to produce silica refractory brick used to line industrial furnaces.

Prices

The average values per ton for the various types of lime are listed in table 8. The values are reported in dollars per metric ton and dollars per short ton. All value data for lime are reported by type of lime produced—high-calcium quicklime, high-calcium hydrate, dolomitic quicklime, dolomitic hydrate, and dead-burned dolomite. Emphasis is placed on the average value per metric ton of lime sold.

Coal is the primary fuel used to manufacture lime in the United States, and even in the most fuel efficient kilns, fuel is currently the largest cost component of production. Beginning in summer 2003, spot prices for high-British-thermal-unit coals from central and northern Appalachia doubled in price, and prices for coals from the Illinois Basin and the Uintah Basin (Utah) increased by 50% to 75% (U.S. Department of Energy, Energy Information Administration, 2006§). Lime companies have been forced to raise lime prices accordingly.

Pushed primarily by significant price increases for quicklime, the average for all types of lime sold increased to $74.00 per metric ton ($67.10 per short ton), an 8% increase compared with the average for 2004. The average value for high-calcium quicklime increased by more than 9% to $70.10 per metric ton ($63.60 per short ton) and the average for dolomitic quicklime increased by more than 7% to $74.80 per metric ton ($67.90 per short ton). Owing to corrections made to data that involved several companies, revisions were made to most 2004 lime prices listed in table 8.

Foreign Trade

The United States exported and imported quicklime, hydrated lime (slaked lime), hydraulic lime, and calcined dolomite (dolomitic lime). Combined exports of lime were 133,000 t (147,000 short tons) valued at $17.5 million, with about 91% exported to Canada, about 8% exported to Mexico, and the remaining 1% going to other countries (table 6). Combined imports of lime were 310,000 t valued at $33 million, with nearly 79% from Canada, nearly 21% from Mexico, and less

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than 1% from other countries (table 7). Canada was the primary source of quicklime (high-calcium and dolomitic) imports and accounted for nearly 82%. With Mexico's proximity to the large soil stabilization markets in Texas, it was not surprising that Mexico was the dominant supplier of hydrated lime, providing 69% of imports.

There is some confusion on what is being reported as imports and exports of hydraulic lime. Natural hydraulic lime is produced from siliceous or argillaceous limestones that contain varying amounts of silica, alumina, and iron. There is no production of natural hydraulic lime in the United States. Synthetic hydraulic lime is produced by mixing hydrated lime with pozzolanic or hydraulic materials such as portland cement. Exports could be synthetic hydraulic lime or, because the chemistry is quite similar, portland cement (or some other hydraulic cement product).

No tariffs are placed on imports of hydraulic lime, quicklime, and slaked lime from countries with normal trade relations (NTR) with the United States. There is a 3% ad valorem tariff on imports of calcined dolomite from NTR countries.

Current Research and Technology

The Ohio Air Quality Development Authority announced that it was partially funding a $2.1 million project at Ohio State University to scale up from laboratory to bench scale a process to capture CO_2 from flue gas using a specially constructed calcium sorbent. The lime-based sorbent will be manufactured by Specialty Minerals, Inc. (subsidiary of Mineral Technologies Inc.), although several other environmental and energy partners are involved. The process is promising because it captures CO_2 from flue gas without first cooling the gas, it captures SO_2, the lime can be regenerated, the reaction creates heat that can be converted into electricity, and the costs of the process are potentially lower than alternative methods (Ohio Air Quality Development Authority, 2005§). Obviously, any lime-based CO_2 capture process will only be practical if the lime sorbent absorbs substantially more CO_2 dioxide than is released in producing the sorbent. The process will require, therefore, that the sorbent be regenerated in a fashion that does not involve the typical release of CO_2 from calcination.

Outlook

High energy prices and rising interest rates may slow the growth of the domestic economy. A slowing economy coupled with continued consolidation of the steel industry and closures of less efficient steel mills may cause a decrease in domestic raw steel production and the quantity of lime consumed by the steel industry. The steel industry has reorganized in recent years and become much more efficient and competitive, but it is still vulnerable to developments in world steel markets. Trade in steel, raw materials, and steel-containing products continues to be susceptible to distortion by foreign government subsidies, trade barriers, and currency manipulation.

The ore concentration market is expected to remain strong, bolstered by increasing production of copper concentrates from operations in Arizona and New Mexico. Domestic production of copper concentrates is forecast to increase by about 25% during 2006-07 compared with 2005 levels (D.L. Edelstein, U.S. Geological Survey, written commun., May 4, 2006). This increase is expected to boost lime sales in the Southwest.

The currently in-place acid rain program (Clean Air Act Amendments) and the clean air interstate rule (finalized in 2005), which covers 28 Eastern States and the District of Columbia and calls for further reductions in SO_2 and NO_x emissions, are expected to lead to the installation of FGD scrubbers on as much as 49 gigawatts of powerplant capacity by 2010. In addition, current regulations covering emissions from small municipal incinerators and waste-to-energy incinerators and the standards the EPA is required to develop for control of hazardous air pollutants from various industrial categories also provide significant growth opportunities for lime in the FGD market. Major areas of complexity and uncertainty, however, involve the trading of SO2 emissions allowances (their availability and cost), the resultant timing of FGD equipment installations, and competition with limestone-based scrubbing systems. Increased hydrate sales are expected for the control of sulfur trioxide emissions from SCR-NOx control systems at powerplants.

On August 10, the President signed the Safe, Accountable, Flexible, Efficient Transportation Equity Act—A Legacy for Users (SAFETEA-LU) (Public Law 109-59). This Act reauthorized Federal surface transportation programs through the end of fiscal year 2009. Total funding in the bill was $286.4 billion for the 6-year authorization period, but in actuality the act provided $244.1 billion for the 5 years remaining before fiscal year 2009 since the previous funding bill expired in 2003. Of this amount, 79% is provided for highway programs. One aspect of the law that will have important impacts on States that pay large amounts into the Highway Trust Fund is the Equity Bonus Program, which ensures that each State's return on its share of contributions to the Highway Trust Fund (in the form of gas and other highway taxes) is at least 90.5% in 2005 and increasing toward a minimum 92% relative rate of return by 2008, while at the same time holding 27 States harmless (meaning they will not receive less actual money than they have in the past). This increase is particularly important to such States as Arizona, California, Colorado, Michigan, and Texas that contribute more money to the Highway Trust Fund than they receive in return in Federal transportation funding. This increased funding helps lime's road stabilization and hot-mix asphalt markets, especially in large-market States like California and Texas. Overall, SAFETEA-LU will essentially be a continuation of previous funding levels for transportation projects, such as highway construction, and will at least provide stability for planning and commissioning of highway transportation projects through 2009. Lime's road stabilization and hot-mix asphalt markets will not receive the big boost that higher funding levels might have provided, but current funding levels will support a continuation of current lime stabilization and hot-mix asphalt sales.

The recent growth in hydrated lime sales for traditional building uses has been driven by low interest rates, which fueled the boom in residential and nonresidential construction. After setting a record for new home construction starts in 2005, new

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home construction starts are expected to decrease in 2006 and 2007 (National Association of Home Builders, 2006§). The nonresidential sector, however, is expected to remain strong (American Institute of Architects, 2006§). Population increases in the South and Southwest will fuel demand for Type S lime for exterior stucco and mortar mixes for concrete blocks, but rising interest rates could have a dampening effect on construction and thus on lime sold for building uses nationwide.

The domestic lime industry is operating at a high utilization rate, and if there is a significant increase in demand, then there may be supply shortages. The industry is adding new capacity in Arkansas, Kentucky, Michigan, Missouri, Pennsylvania, and Texas, so adequate supplies will be available in the near future. The continued closure of smaller, older lime plants for economic reasons, including the cost of complying with new environmental regulations, is likely.

Overall, lime demand is expected to remain strong in 2006, but much depends on how the economy performs, especially with respect to the steel market. Driven by increased copper production, the ore concentration market is expected to expand during the next couple of years. Asphalt and soil stabilization will likely be the strongest markets as was the case in 2005. Prices are expected to continue moving upward, but probably not as steeply as in 2005.

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TABLE 1
SALIENT LIME STATISTICS[1, 2]

		2001	2002	2003	2004	2005
United States[3]						
Number of plants[4]		103	99	96	91 r	94
Sold or used by producers:						
Quicklime:						
High-calcium	thousand metric tons	13,600	13,400	13,900	14,200	14,100
Dolomitic	do.	2,580	2,420	2,460	3,020 r	2,990
Total	do.	16,200	15,800	16,400	17,200	17,100
Hydrated lime:						
High-calcium	thousand metric tons	2,030	1,500	2,140	2,140 r	2,220
Dolomitic	do.	447	431	464	421 r	474
Total	do.	2,470	1,930	2,610	2,570 r	2,700
Dead-burned dolomite[5]	do.	200	200	200	200	200
Grand total:						
Quantity	do.	18,900	17,900	19,200	20,000	20,000
Value[6]	thousand dollars	1,160,000	1,120,000	1,240,000	1,370,000	1,500,000
Average value	dollars per metric ton	61.30	62.60	64.80	68.90 r	75.00
Lime sold	thousand metric tons	17,000	16,500	17,700	18,400 r	18,600
Lime used	do.	1,840	1,340	1,470	1,520 r	1,490
Exports:[7]						
Quantity	do.	96	106	98	100	133
Value	thousand dollars	11,900	13,100	13,700	14,300 r	17,500
Imports for consumption:[7]						
Quantity	thousand metric tons	115	157	202	232	310
Value	thousand dollars	15,100	19,700	22,500	25,900	33,000
Consumption, apparent[8]	thousand metric tons	18,900	17,900	19,300	20,100 r	20,200
World, production	do.	121,000	120,000 r	125,000 r	127,000 r	127,000 e

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]To convert metric tons to short tons, multiply metric tons by 1.102.

[3]Excludes regenerated lime; includes Puerto Rico.

[4]Includes producer-owned hydrating plants not located at lime plants.

[5]Data are rounded to no more than one significant digit to protect company proprietary data.

[6]Selling value, free on board plant, excluding cost of containers.

[7]Source: U.S. Census Bureau.

[8]Defined as sold or used plus imports minus exports.

TABLE 2
LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1, 2]

State	Plants[3]	Hydrated (thousand metric tons)[4]	Quicklime[5] (thousand metric tons)[4]	Total (thousand metric tons)[4]	Value (thousands)
2004:					
Alabama	5	165	2,120	2,280	$164,000
Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming	18	299	2,340	2,640	168,000
California, Oregon, Washington	8	87	291	378	33,200
Illinois, Indiana, Missouri	6	465	3,310 r	3,770 r	263,000 r
Iowa, Nebraska, South Dakota	3	W	W	370 r	24,500 r
Kentucky, Tennessee, West Virginia	5	127	2,710	2,830	176,000
Ohio	7	105	1,770	1,880	133,000 r
Pennsylvania	6	171	1,050	1,220	100,000
Texas	5	630	996	1,630	115,000
Wisconsin	4	181	670	850	53,900
Other[6]	24	336 r	2,150 r	2,140	141,000 r
Total	91 r	2,570 r	17,400	20,000	1,370,000

See footnotes at end of table.

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TABLE 2—Continued

LIME SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1, 2]

State	Plants[3]	Hydrated (thousand metric tons)[4]	Quicklime[5] (thousand metric tons)[4]	Total (thousand metric tons)[4]	Value (thousands)
2005:					
Alabama	5	145	2,100	2,240	$180,000
Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming	19	386	2,670	3,060	221,000
California, Oregon, Washington	8	69	299	368	44,100
Illinois, Indiana, Missouri	7	510	3,250	3,760	280,000
Iowa, Nebraska, South Dakota	3	W	W	366	26,400
Kentucky, Tennessee, West Virginia	5	124	2,670	2,790	188,000
Ohio	7	130	1,660	1,790	130,000
Pennsylvania	7	161	936	1,100	104,000
Texas	5	628	982	1,610	112,000
Wisconsin	4	195	694	888	61,300
Other[6]	24	348	2,090	2,440	156,000
Total	94	2,700	17,400	20,000	1,500,000

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."

[1]Excludes regenerated lime.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Includes producer-owned hydrating plants not located at lime plants.

[4]To convert metric tons to short tons, multiply metric tons by 1.102.

[5]Includes dead-burned dolomite.

[6]Includes Arkansas, Florida, Georgia, Louisiana, Massachusetts, Michigan, Minnesota, North Dakota, Oklahoma, Puerto Rico, Virginia, and data indicated by the symbol W.

TABLE 3

LIME SOLD AND USED BY PRODUCERS IN THE UNITED STATES, BY RANGE OF PRODUCTION[1, 2]

	2004			2005		
Range of production	Plants	Quantity (thousand metric tons)[3]	Percentage of total	Plants	Quantity (thousand metric tons)[3]	Percentage of total
Less than 25,000 metric tons	18 [r]	253 [r]	1 [r]	19	242	1
25,000 to 100,000 tons	13 [r]	437 [r]	2 [r]	13	415	2
100,000 to 200,000 tons	19 [r]	1,930 [r]	10 [r]	19	1,850	9
200,000 to 300,000 tons	14 [r]	2,780 [r]	14 [r]	17	3,330	17
300,000 to 400,000 tons	11	3,400 [r]	17 [r]	9	2,610	13
400,000 to 600,000 tons	6 [r]	2,660 [r]	13 [r]	6	2,430	10
More than 600,000 tons	10	8,500	43	11	9,180	48
Total	91 [r]	20,000	100	94	20,000	100

[r]Revised.

[1]Excludes regenerated lime. Includes Puerto Rico.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]To convert metric tons to short tons, multiply metric tons by 1.102.

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TABLE 4

LIME SOLD AND USED BY PRODUCERS IN THE UNITED STATES, BY USE[1, 2]

(Thousand metric tons[3] and thousand dollars)

Use	2004		2005	
	Quantity[4]	Value[5]	Quantity[4]	Value[5]
Chemical and industrial:				
Fertilizer, aglime and fertilizer	33	3,090	29	3,300
Glass	120	8,250	148	11,200
Paper and pulp	802	51,600	772	55,500
Precipitated calcium carbonate	1,180	82,800	1,130	92,800
Sugar refining	707	41,300 r	834	63,900
Other chemical and industrial[6]	1,360 r	107,000 r	1,380	108,000
Total	4,200 r	294,000 r	4,290	335,000
Metallurgical:				
Steel and iron:				
Basic oxygen furnaces	3,070	214,000	2,680	208,000
Electric arc furnaces	2,690	185,000	2,980	230,000
Other steel and iron	425	27,500	323	23,000
Total	6,190	427,000	5,980	461,000
Nonferrous metallurgy[7]	1,240	75,700	1,290	87,500
Total	7,430	503,000	7,270	548,000
Construction:				
Asphalt	421 r	33,800 r	453	38,000
Building uses	456 r	48,300 r	493	54,000
Soil stabilization	1,600 r	110,000	1,730	120,000
Other construction	12	1,070	55	3,930
Total	2,490 r	193,000 r	2,730	216,000
Environmental:				
Flue gas desulfurization (FGD):				
Utility powerplants	3,510 r	213,000 r	3,470	217,000
Incinerators	135	9,990	133	12,000
Industrial boilers and other FGD	49	4,070	50	4,620
Total	3,690 r	227,000 r	3,650	234,000
Sludge treatment:				
Sewage	200	14,200	176	14,400
Other, industrial, hazardous, etc.	116	8,650	117	9,380
Total	316	22,900	293	23,700
Water treatment:				
Acid-mine drainage	101 r	7,500 r	118	11,000
Drinking water	865 r	59,400 r	906	67,400
Wastewater	503	37,300	463	38,200
Total	1,470	104,000 r	1,490	117,000
Other	138 r	10,200 r	98	8,110
Total	5,620 r	364,000 r	5,530	382,000
Refractories (dead-burned dolomite)	200 [8]	20,700 [9]	200 [8]	21,600 [9]
Grand total	20,000	1,370,000 r	20,000	1,500,000

rRevised.

[1]Excludes regenerated lime. Includes Puerto Rico.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]To convert metric tons to short tons, multiply metric tons by 1.102.

[4]Quantity includes lime sold and used, where "used" denotes lime produced for internal company use for magnesia, paper and pulp, precipitated calcium carbonate, basic oxygen furnaces, and refractories.

[5]The U.S. Geological Survey does not collect value data by end use; the values shown are mainly derived from average lime values.

[6]May include alkalis, calcium carbide and cyanamide, calcium hypochlorite, citric acid, food (animal or human), oil and grease, oil well drilling, petrochemicals, tanning, and other uses. Magnesia is included here to avoid disclosing proprietary data.

[7]Includes aluminum and bauxite, magnesium, ore concentration (such as copper and gold) and other.

[8]Data are rounded to one significant digit to protect company proprietary data.

[9]Values are estimated based on average value per metric ton of dead-burned dolomite for each year.

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TABLE 5

HYDRATED LIME SOLD OR USED IN THE UNITED STATES, BY END USE[1, 2]

(Thousand metric tons[3] and thousand dollars)

Use	2004		2005	
	Quantity[4]	Value[5]	Quantity[4]	Value[5]
Chemical and industrial	515 r	51,400 r	539	55,400
Construction:				
Asphalt	354 r	29,400 r	408	34,900
Building uses	442 r	47,300 r	481	53,000
Soil stabilization	508 r	38,900 r	466	32,800
Other construction	8	786	5	514
Total	1,310 r	116,000 r	1,360	121,000
Environmental:				
Flue gas desulfurization (FGD):				
Utility powerplants	149 r	10,700 r	220	13,300
Incinerators	21	1,910	21	2,170
Industrial boilers and other FGD	22	2,310	27	2,840
Total	192 r	14,900 r	268	18,300
Sludge treatment:				
Sewage	39	3,230	40	3,700
Other sludge treatment	43	4,080	54	5,090
Total	82	7,310	94	8,800
Water treatment:				
Acid-mine drainage	61 r	4,990 r	85	8,460
Drinking water	148 r	13,100 r	127	12,200
Wastewater	175	14,900	151	14,400
Total	384 r	33,000 r	363	35,100
Other environmental	38 r	3,220 r	23	2,240
Metallurgy	43	3,760	47	4,500
Grand total	2,570 r	230,000 r	2,700	246,000

rRevised.

[1]Excludes regenerated lime. Includes Puerto Rico.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]To convert metric tons to short tons, multiply metric tons by 1.102.

[4]Quantity includes hydrated lime sold and used, where "used" denotes lime produced for internal company use in building, chemical and industrial, and metallurgical sectors.

[5]The U.S. Geological Survey does not collect value data by end use; the values shown are mainly derived from average lime values.

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TABLE 6
U.S. EXPORTS OF LIME, BY TYPE[1]

Type	2004 Quantity (metric tons)[2]	2004 Value[3]	2005 Quantity (metric tons)[2]	2005 Value[3]
Calcined dolomite:				
Canada	23,400	$5,610,000	27,000	$6,490,000
Germany	--	--	16	3,840
Mexico	111	32,700	19	5,280
Other[4]	111	54,900	361	151,000
Total	23,600	5,690,000	27,400	6,650,000
Hydraulic lime:				
Bahamas, The	146	32,500	76	13,100
Canada	6,710	966,000	3,340	623,000
Mexico	14	12,000	--	--
Other[5]	216	97,000	235	191,000
Total	7,080	1,110,000	3,650	827,000
Quicklime:				
Bahamas, The	320	66,600	372	87,500
Canada	55,300	5,040,000	83,000	7,200,000
Costa Rica	377	164,000	80	22,800
Mexico	4,310	594,000	8,710	1,010,000
Other[6]	1 r	54,900	134	26,600
Total	60,300	5,920,000 r	92,300	8,350,000
Slaked lime, hydrate:				
Canada	6,030	944,000	7,400	1,140,000
Mexico	1,010	259,000	1,330	333,000
Philippines	181	24,100	431	62,000
Other[7]	1,330	311,000	611	181,000
Total	8,550	1,540,000	9,760	1,720,000
Grand total	99,600	14,300,000 r	133,000	17,500,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]To convert metric tons to short tons, multiply metric tons by 1.102.

[3]Declared free alongside ship valuation.

[4]Includes Finland (2004), Japan, Uruguay, and Venezuela (2005).

[5]Includes Argentina (2005), Australia (2005), Bahrain (2005), Bermuda (2005), Honduras, Israel (2005), Japan, the Republic of Korea (2005), Lithuania (2005), the Philippines (2004), and the United Kingdom (2005).

[6]Includes Argentina (2005), Australia, Chile (2004), the Dominican Republic (2005), and Singapore (2004).

[7]Includes Ecuador (2005), Honduras (2004), Hong Kong (2005), Malaysia (2005), the Netherlands (2004), South Africa, Trinidad and Tobago (2004), and the United Kingdom.

Source: U.S. Census Bureau.

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TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF LIME, BY TYPE[1]

Type	2004 Quantity (metric tons)[2]	2004 Value[3]	2005 Quantity (metric tons)[2]	2005 Value[3]
Calcined dolomite:				
Canada	21,600	$2,120,000	43,700	$4,330,000
Mexico	538	66,700	194	41,000
Other[4]	158	69,100	164	83,300
Total	22,300	2,250,000	44,000	4,460,000
Hydraulic lime:				
Canada	4	2,100	30	2,680
Mexico	4,440	489,000	1,130	133,000
Other[5]	746	378,000	356	328,000
Total	5,190	869,000	1,520	463,000
Quicklime:				
Canada	127,000	16,400,000	190,000	21,300,000
Mexico	47,000	2,760,000	40,500	2,310,000
Other[6]	262	126,000	989	393,000
Total	174,000	19,200,000	232,000	24,000,000
Slaked lime, hydrate:				
Canada	9,200	976,000	9,740	1,070,000
Mexico	20,400	2,240,000	22,500	2,500,000
Other[7]	354	287,000	538	516,000
Total	30,000	3,500,000	32,700	4,080,000
Grand total	232,000	25,900,000	310,000	33,000,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]To convert metric tons to short tons, multiply metric tons by 1.102.

[3]Declared cost, insurance, and freight valuation.

[4]Includes China and Spain.

[5]Includes Belgium (2004), the Dominican Republic (2004), France, Germany (2004), Israel (2005), Italy, and Switzerland (2004).

[6]Includes Australia (2004), Belgium (2004), Brazil (2004), China, Colombia (2005), Denmark (2005), Germany (2005), Japan, Saudi Arabia (2004), Sweden (2004), and the United Kingdom (2005).

[7]Includes Belgium, Brazil (2004), France, Germany, Hong Kong (2005), Italy, Japan, the Netherlands (2005), Switzerland (2005), and the United Kingdom.

Source: U.S. Census Bureau.

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TABLE 8
LIME PRICES[1]

Type	2004		2005	
	Dollars per metric ton	Dollars per short ton[2]	Dollars per metric ton	Dollars per short ton[2]
Sold and used:				
Quicklime	65.40 r	59.40 r	72.10	65.50
Hydrate	89.70 r	81.40 r	91.10	82.70
Dead-burned dolomite	93.80	85.10	96.20	87.20
Average all types	68.90 r	62.50 r	75.00	68.00
Sold:				
High-calcium quicklime	64.10 r	58.20 r	70.10	63.60
Dolomite quicklime	69.60 r	63.10 r	74.80	67.90
Average quicklime	65.10 r	59.00 r	70.90	64.30
High-calcium hydrate	85.60 r	77.60 r	86.60	78.60
Dolomite hydrate	110.60 r	100.40 r	112.30	101.80
Average hydrate	89.70 r	81.40 r	91.10	82.70
Dead-burned dolomite	97.50	88.50	107.10	97.20
Average all types	68.70 r	62.30 r	74.00	67.10

rRevised.

[1]Average value per ton, on a free on board plant basis, including cost of containers.

[2]Conversions were made from unrounded metric ton values and may not be conversions of the rounded values.

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TABLE 9

QUICKLIME AND HYDRATED LIME, INCLUDING DEAD-BURNED DOLOMITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Australia[e]	1,500	1,500	1,500	1,500	1,500
Austria[e]	2,000	2,000	2,000	2,000	2,000
Belgium[e, 4]	2,000	2,000	2,000	2,000	2,000
Brazil[e]	6,300 [5]	6,500	6,500	6,500	6,500
Bulgaria	2,025	1,136	2,902	2,900 [e]	2,500
Canada	2,213	2,248	2,216	2,200 [e]	2,250 [5]
Chile[e]	1,000	1,000	1,000	1,000	1,000
China[e]	22,000	22,500	23,000	23,500	24,000
Colombia	1,300	1,300	1,300 [e]	1,300 [e]	1,300
Czech Republic[e]	1,300	1,120	1,263 [5]	1,300	1,300
Egypt[e]	800	800	800	800	800
France[e, 4]	3,000	3,000	3,000	3,000	3,000
Germany	6,630	6,620	6,637	6,680 [r]	6,700
India[e]	910	900	900	900	920
Iran[e]	2,000	2,200	2,300 [r]	2,500 [r]	2,500
Italy[e, 6]	3,500	3,000	3,000	3,000	3,000
Japan, quicklime only	7,586	7,420	7,953	8,507 [r]	8,600
Mexico[e, 4]	4,800	5,100	5,700	5,700	5,700
Poland	2,049	1,960	1,955	1,950 [e]	2,000
Romania	1,790	1,829	2,025	2,000 [e]	2,000
Russia[e]	8,000	8,000	8,000	8,200 [r]	8,200
Slovakia	816	912	847	850 [e]	850
Slovenia	1,434	1,636	1,500	1,500 [e]	1,500
South Africa, burnt lime sales	1,615	1,585 [r]	1,518 [r]	1,738 [r]	1,400
Spain[e, 4]	1,700	1,800	1,800	1,800	1,800
Taiwan[e]	800	750	800	800	800
Turkey[e, 4]	3,200	3,300	3,300	3,400	3,400
United Kingdom[e]	2,500	2,000	2,000	2,000	2,000
United States, including Puerto Rico, sold or used by producers	18,900	17,900	19,200	20,000	20,000 [5]
Vietnam	1,351	1,426	1,450 [e]	1,500 [e]	1,650
Other[e]	6,140 [r]	6,340 [r]	6,220 [r]	6,220 [r]	6,230
Total	121,000	120,000 [r]	125,000 [r]	127,000 [r]	127,000

[e]Estimated. [r]Revised.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through March 31, 2006.

[3]In addition to the countries listed, Argentina, Chad, Iraq, Nigeria, Pakistan, Syria, and several other nations produce lime, but output data are not reported; available general information is inadequate to formulate reliable estimates of output levels.

[4]Sales only; data may be incomplete.

[5]Reported figure.

[6]Includes hydraulic lime.

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LITHIUM

By Joyce A. Ober

Domestic survey data and tables were prepared by Hoa Phamdang, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

In 2005, lithium consumption in the United States was estimated to be 2,500 metric tons (t) of contained lithium, nearly 32% more than the estimate for 2004 and 79% more than in 2003. Increased U.S. consumption likely is a result of a general improvement in the domestic economy that created additional consumption in most industrial uses and significantly increased demand for lithium in battery applications. Lithium compounds consumed in the United States were produced at a single domestic operation in Nevada and imported from Argentina and Chile.

Chile has been the world's leading producer of lithium carbonate since 1997, the year that it first surpassed the United States in production. Production in Chile was from two lithium brine operations on the Salar de Atacama in the Andes Mountains and two lithium carbonate plants in Antofagasta. In the United States, production continued at a single lithium brine operation with an associated lithium carbonate plant in Nevada. Lithium carbonate and lithium chloride also were produced from brines from the Salar del Hombre Muerto in the Andes Mountains in Argentina. China was the only country producing large quantities of lithium carbonate from lithium minerals. Australia was, by far, the leading producer of lithium concentrates, but Brazil, Canada, Portugal, and Zimbabwe also produced significant quantities. A large percentage of the lithium carbonate produced in South America was exported to the United States for consumption in industrial applications and as feed material for the production of downstream lithium compounds, such as lithium hydroxide monohydrate, lithium metal, and organic lithium compounds.

Production

The U.S. Geological Survey (USGS) collects domestic production data for lithium from a voluntary canvass of U.S. operations. The single U.S. lithium carbonate producer, Chemetall Foote Corp. (a subsidiary of the German company Chemetall GmbH), responded to the survey, representing 100% of total production. Production and stock data were withheld from publication to avoid disclosing company proprietary data (table 1).

Chemetall Foote produced lithium carbonate from brines near Silver Peak, NV. The company's other U.S. lithium operations included a lithium hydroxide plant in Silver Peak; a butyllithium plant in New Johnsonville, TN; and facilities for producing downstream lithium compounds in Kings Mountain, NC. Chemetall Foote's subsidiary in Chile, Sociedad Chilena de Litio Ltda. (SCL) produces lithium carbonate from a brine deposit.

FMC Corp.'s Lithium Division produced a full range of downstream compounds, lithium metal, and organic lithium compounds at its facilities in Bessemer City, NC, and Bayport, TX. FMC met its lithium carbonate requirements with material produced at its Argentine operation and through a long-term agreement with Chilean producer Sociedad Química y Minera de Chile S.A. (SQM) to supply it with lithium carbonate produced at SQM's brine operation. FMC also produced lithium chloride in Argentina in 2005.

Consumption

Lithium is sold as brines, compounds, metal, or mineral concentrates depending on the end use. Lithium's electrochemical reactivity and other unique properties have resulted in many commercial lithium products. For many years, the majority of lithium compounds and minerals were used in the production of ceramics, glass, and primary aluminum, but growth in lithium battery use and decreased use of lithium in aluminum production has resulted in batteries gaining market share and perhaps soon becoming the leading end use for lithium. SQM listed main uses for lithium in 2004 as follows: ceramics and glass, 21%; batteries, 19%; lubricating greases, 16%; pharmaceuticals and polymers, 9%; air conditioning, 8%; primary aluminum production, 6%; and other uses, 21% (Sociedad Química y Minera de Chile S.A., 2005). The "other uses" category represents several smaller end uses including alloys, construction, dyestuffs, industrial bleaching and sanitation, pool chemicals, and specialty inorganics (FMC Corp., 2006§[1]).

In 2005, lithium consumption in the United States was estimated to be 2,500 t of contained lithium, nearly 32% more than the estimate for 2004 and 79% more than in 2003. The recent recovery can be attributed to increased consumption in all end uses except aluminum as a result of the upswing in the domestic economy and increased demand in a few rapidly expanding end uses. Domestic end uses for lithium materials may not directly correspond to worldwide consumption, but the data necessary for making more reliable estimates are not available. Growth areas are believed to be similar globally, but individual markets may differ by location.

If lithium concentrates are included in lithium consumption estimates, the leading use of lithium in the United States may be in ceramics and glass manufacturing processes. No lithium concentrates are produced in the United States for direct application in ceramics and glass manufacture, and import statistics do not specifically identify lithium ore imports, making it difficult to determine definitive end-use estimates. The addition of lithium as lithium carbonate or lithium concentrates to a glass melt lowers the process melting point, reduces the coefficient of thermal expansion and the viscosity, and eliminates the use of more toxic compounds. The production of ceramics and glass was the only commercial use for lithium mineral concentrates. The manufacture of thermal-shock-resistant cookware (pyroceramics) consumed the majority of lithium used in the ceramics and glass industry.

[1]References that include a section mark (§) are found in the Internet References Cited section.

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Low-iron spodumene and petalite were sources of the lithium used to improve the physical properties of container and bottle glass, as well as sources of alumina, another important component of glass. Glass manufacturers used lithium in container and bottle glass to produce a lighter weight, thinner walled product. Lithium concentrates are the predominant lithium source for ceramics and glass uses, but lithium carbonate also is used.

Lithium batteries may now be the second ranked end use for lithium and might become the leading end use in the near future. Many major battery manufacturers marketed some type of lithium battery, exploiting the many advantages of lithium batteries compared with older battery technologies. Research and development continued, and innovative rechargeable battery configurations continued to be developed to meet the changing requirements of electronic equipment, such as portable telephones, portable computers, and video cameras. Worldwide, rechargeable lithium batteries power more than 60% of cellular telephones and 90% of laptop computers (FMC Corp., 2006§).

Nonrechargeable lithium batteries offer improved performance compared with alkaline batteries at a slightly higher cost and have been commercially available for more than 10 years. They are used in cameras, electronic games, microcomputers, small appliances, toys, and watches. The military purchases lithium batteries for a variety of applications.

The multipurpose grease industry was an important market for lithium in 2005. Lithium hydroxide monohydrate was the compound used to produce lithium lubricants. Lithium-base greases were favored for their retention of lubricating properties over a wide temperature range; good resistance to water, oxidation, and hardening; and formation of a stable grease on cooling after melting. These greases are used in aircraft, automotive, industrial, marine, and military applications.

Another major end use for lithium compounds was as catalysts and reagents in the production of synthetic rubbers, plastics, and pharmaceuticals. N-butyllithium, an organic lithium compound, was used to initiate the reactions between styrene and butadiene to form abrasion-resistant synthetic rubbers that require no vulcanization. Other organic lithium compounds were used as catalysts for the production of plastics, such as polyethylene. Lithium metal and organic compounds also were used as catalysts in the production of pharmaceuticals, including anticholesterol agents, antihistamines, contraceptives, sleep inducers, steroids, tranquilizers, vitamin A, and other products. Pharmaceutical-grade lithium carbonate was used in the treatment of manic-depressive psychosis, the only treatment approved by the U.S. Food and Drug Administration in which lithium was consumed by the patient.

The use of lithium in primary aluminum production has decreased steadily since 2000 in the United States, as domestic aluminum production declined. Adding lithium carbonate to aluminum potlines lowers the melting point of the cryolite bath, allows a lower operating temperature for the cells, increases the electrical conductivity, and decreases bath viscosity. These factors contribute to increased production without changing any other operating conditions especially in older smelters, like those in North America. Lithium carbonate additions also have the potential environmental benefit of reducing fluorine emissions by 20% to 30% (Chemetall GmbH, undated§).

Small quantities of other lithium compounds were important to many industries. Aircraft manufacturers in several countries sometimes use aluminum-lithium alloys for wing and fuselage skin or for structural members in different types of aircraft to reduce the weight of the aircraft by more than 10%, allowing significant fuel savings during the life of the aircraft. Lithium was being used increasingly as a concrete additive to prevent or mitigate premature deterioration of concrete through alkali silica reactivity, lithium compounds were added to fast-setting cements, floor screeds, joint sealing mortars, and cement based adhesives to accelerate setting and hardening rates (FMC, 2006§; Chemetall GmbH, undated§).

Lithium chloride and lithium bromide were used in industrial air-conditioning and commercial dehumidification systems and in the production of sophisticated textiles. Sanitizers for commercial glassware, public restrooms, and swimming pools contained lithium hypochlorite, as did dry bleaches for commercial laundries. Lithium metal was used as a scavenger to remove impurities from bronze and copper, and anhydrous lithium chloride was used as a component in fluxes for hard-to-weld metals, such as aluminum and steel alloys.

Prices

Lithium pricing became very competitive when SQM entered the market in 1998, and it has been difficult to obtain reliable price information since that time. Companies may announce price hikes, but they are reported relative only to previous prices. Producers negotiate with consumers on an individual basis; price information is not usually reported.

In recent years, customs values for lithium carbonate imports to the United States seemed to be a good indication of the trends in lithium pricing, although they never exactly reflected the producers' prices for lithium carbonate. In 2005, this did not seem to be the case. The average customs unit value for imported lithium carbonate was $1.46 per kilogram, about 15% lower than in 2004; lithium producers, however, reported increased prices for most lithium compounds in contrast to the decreased customs values. Average unit vales of exported lithium carbonate were about the same in 2005 as the previous year and are more than twice those of imported material. This suggests that the material being exported from the United States may be higher quality lithium carbonate than what is imported.

Foreign Trade

In 2005, total exports of lithium compounds from the United States increased slightly compared with those of 2004. About 62% of all U.S. exports of lithium compounds went to China, Germany, Japan, and Russia, all with more than 500 t. The remainder was divided among many other countries (table 2).

Imports of lithium compounds increased by 23% in 2005 as the domestic economy continued to improve. In 2005, 75% of lithium chemical imports came from Chile, 24% came from Argentina, and 1% from other countries (table 3). Lithium concentrates from Australia, Canada, and Zimbabwe may have entered the United States, but because these materials have no unique import code, no import data were available.

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World Review

A small number of countries throughout the world produced lithium concentrates and brine. Chile, China, and the United States were the leading producers of lithium carbonate. Significant quantities of lithium compounds and concentrates also were produced in Argentina, Australia, Brazil, Canada, Portugal, Russia, and Zimbabwe. Congo (Kinshasa), Namibia, Rwanda, and South Africa produced concentrates in the past. Production figures for lithium mineral concentrates, lithium carbonate, and lithium chloride are listed in table 4. Pegmatites containing lithium minerals have been identified in Austria, France, India, Ireland, Mozambique, Spain, and Sweden, but economic conditions have not favored development of the deposits. Lithium has been identified in subsurface brines in Bolivia, China, and Israel. Companies in France, Germany, Japan, Taiwan, and the United Kingdom produced downstream lithium compounds from imported lithium carbonate.

Estimates of the total world lithium market averaged 14,100 t of lithium contained in minerals and compounds in 2003, the latest year for which this type of information was available. About 11,300 t of lithium was consumed as compounds, and the remainder, as concentrates (Ebensperger and others, 2005). More recent data were not available, but some estimates on growth can be made based on recent growth rates reported by SQM. That company estimated demand for their lithium materials to have grown by 10% in 2004. Assuming similar growth in 2005 for all lithium compounds consumption, total consumption of lithium in minerals and compounds can be estimated to be about 17,000 t, with nearly 14,000 t in compounds (Sociedad Química y Minera de Chile S.A., 2005).

Argentina.—FMC's Argentine facility at the Salar de Hombre Muerto was designed to produce about 12,000 metric tons per year (t/yr) of lithium carbonate and about 5,500 t/yr of lithium chloride (North American Mineral News, 1998). Production of both compounds reached record levels in 2004, with lithium chloride production surpassing reported capacity. It is not known whether the plant was expanded or if improved efficiencies made the extra production possible.

Admiralty Resources NL of Melbourne, Australia, was considering the development of the Salar de Rincon brine resources in Argentina, expecting to begin producing lithium chloride in 2007. Initial capacity was expected to be about 12,000 t/yr (Admiralty Resources NL, 2005).

Australia.—Sons of Gwalia Ltd. is the leading lithium mineral producer with 60% of world lithium concentrate capacity. It produces spodumene concentrates at the Greenbushes Mine in Western Australia. The company markets products containing 2.2% to 3.5% lithium (Crossley, 2003b). Spodumene concentrates are sold for consumption in ceramics and glass and also are exported to China where it is used in glass and as a raw material for the production of lithium carbonate.

Chile.—With two large brine operations at the Salar de Atacama and their associated lithium carbonate plants, Chile was the leading lithium carbonate producer in the world. Chemetall Foote's plant first produced lithium carbonate in 1984, and current capacity is about 14,500 t/yr. The plant uses this lithium carbonate as feedstock for some of its downstream chemical production in the United States and supplies the operations of its parent company, Chemetall, in Germany and Taiwan (Chemetall GmbH, undated§). SQM completed its first full year of production in 1997 with the capacity to produce about 23,000 t/yr of lithium carbonate (Schmitt, 2001). Both Chilean companies transported concentrated brines from the Salar de Atacama to lithium carbonate plants near Antofagasta.

In 2005, SQM produced at its full capacity of 27,000 t/yr and was working to increase capacity to 40,000 t/yr by 2008. The company reported that its share of the world lithium carbonate market has grown to 40% (Harris, 2005). SQM completed its 6,000-t/yr lithium hydroxide plant in late 2005 (Sociedad Química y Minera de Chile S.A., undated§).

China.—China is the only country that continued to produce large quantities of lithium carbonate from spodumene. China Xinjuang Nonferrous Metals Corporation of Mingyuan produced lithium carbonate from domestic and imported Australian ore (Ebensperger and others, 2005). Additional lithium carbonate was imported into China from Chile and the United States. Lithium brines were believed to be the largest lithium resources in China, containing 80% of the country's reserves (Crossley, 2003a).

China was developing a project to recover lithium carbonate from the brines of the Zabayu salt lake in Tibet. Capacity was expected to be 5,000 t/yr (Chinanews, 2005§). A similar project was being developed by a Canadian company, Sterling Group Ventures, Inc., and its wholly-owned subsidiary Micro Express Holding, Inc. The company signed an agreement with the Beijing Mianping Salt Lake Research Institute to develop another brine deposit to produce lithium carbonate in Tibet. The $30 million operation also is expected to produce 5,000 t/yr of lithium carbonate (Sterling Group Venture, Inc., 2005).

Current Research and Technology

Carbon Dioxide Absorption.—Researchers in Japan discovered a series of lithium-containing oxides that absorb 10 times more carbon dioxide than other carbon dioxide absorbents. The reaction between carbon dioxide and the lithium oxide materials occurs instantaneously at temperatures up to 700° C and is reversed at higher temperatures. Lithium silicate showed great potential because of its large absorption capacity, rapid absorption, effectiveness over a wide range of temperatures and carbon dioxide concentrations, and reusability. This process would be used to remove carbon dioxide from flue gases at powerplants and other facilities that release large quantities of carbon dioxide into the atmosphere, reducing the possible contribution to global warming, thought to be caused, at least in part, by excess carbon dioxide in the atmosphere (Kato and others, 2005).

Hybrid-Electric Vehicles.—In 2005, most hybrid electric vehicles (HEVs) used nickel-metal-hydride batteries, but many experts believed that lithium-ion batteries would power the next-generation of HEVs because they offer advantages in power generation, size, weight, cycle life, and cost. HEVs offer fuel economy improvements of 5% to 35% compared with those of vehicles powered exclusively by internal combustion engines. The U.S. Government funded a research program to develop an abuse-tolerant lithium-ion battery with extended life

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and improved power-to-weight performance compared with the batteries used in early HEVs (Johnson Controls, Inc., 2006).

Medical Devices.—Lithium batteries have found widespread acceptance in implantable medical devices such as pacemakers and electronic stimulators that help restore function in the brains of people with Parkinson's disease. New technology has made it possible to make batteries smaller and longer lasting. It is expected that soon an implanted lithium battery incorporating organosilicon compounds may be able to be recharged from outside the body. These new batteries are projected to last 12 years (Devitt, 2005§).

Nanotechnology.—Nanotechnology, the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, has made it possible to make rechargeable batteries that can charge and discharge very rapidly, making it reasonable to expect that lithium-ion batteries could be used in many more applications in the near future. Lithium-ion batteries were being considered for power hand tools, flywheel uninterrupted power supplies, and HEVs. This technology makes it possible to completely recharge the batteries in an electric vehicle in about the same time it currently takes to refill the gas tank on a vehicle with an internal combustion engine (Gotcher, 2005).

Thin Film Technology.—The Oak Ridge National Laboratory was developing thin-film lithium batteries and materials for these batteries that withstand a wide range of temperatures from below 0° to 250° C. Thin-film lithium batteries last longer; hold their charge better during storage; recharge faster with no memory effects; can be recharged many times; and can be made much smaller, lighter, and more flexible than more traditional batteries. Because all their components are solid, there are no such potential problems as corrosion, freezing, and leakage. They are more expensive than more common batteries and are not available in standard cell sizes, but they are more attractive for modern technology developments like package tracking systems, "smart cards," and many other innovative devices (Oak Ridge National Laboratory, 2005).

Outlook

Although traditional markets are still important to the lithium industry, batteries are rapidly gaining in importance and could very soon be the major market for lithium materials of all kinds.

The market for lithium batteries has been increasing by more than 20% per year in the past few years. Lithium-ion and lithium-polymer batteries appear to have the greatest potential for growth. First introduced in 1993, the market for these rechargeable batteries was estimated to be $4 billion in 2005 (Chemical & Engineering News, 2006). Most lithium batteries that are sold are the lithium-ion type, but lithium-polymer batteries are gaining in popularity and represent about 10% of the battery market. Lithium-polymer batteries are more attractive to many original equipment manufacturers because they can be constructed in unusual shapes to more easily fit into the devices that they power (Crossley, 2003b).

New developments in lithium battery technology, including the use of nanotechnology that enables very fast charges for rechargeable lithium batteries, hold the potential for large growth. Widespread use of lithium-ion batteries in HEVs could create tremendous demand for lithium in the near future.

Other lithium markets are also growing but at lower rates than batteries. Lithium producers had diverse opinions on what other areas offer the most potential for growth. One producer reported growth in construction uses, especially in fast-setting concrete. Another company experienced its largest growth in the use of organic lithium compounds used as pharmaceutical catalysts. Lithium bromide consumption for air conditioning was reported to be increasing by some producers, but on the decline, especially in the United States, by another. Better estimates of actual markets were not possible because details that closely define these markets were not publicly available.

Most experts, however, agree that lithium batteries hold the greatest promise for expanding the demand for lithium. Established uses in portable devices continue to increase as consumers demand longer lasting, lighter weight, and more reliable power systems. If and when lithium batteries become the accepted battery type for HEVs, demand is likely to expand rapidly. Brine operations can be expected to expand capacity relatively quickly to supply increasing demand. It is possible, however, that if the market grows large enough, lithium minerals may once again be attractive raw materials for lithium carbonate production.

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TABLE 1
SALIENT LITHIUM STATISTICS[1]

(Metric tons of contained lithium)

	2001	2002	2003	2004	2005
United States:					
Production	W	W	W	W	W
Exports[2]	1,480	1,620	1,520	1,690	1,720
Imports[2]	1,990	1,920	2,200	2,910	3,580
Consumption, estimated	1,400	1,100	1,400	1,900	2,500
Rest of world, production[3]	15,400	16,400	19,100	20,300 r	20,600 e

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits.

[2]Compounds. Source: U.S. Census Bureau.

[3]Mineral concentrate and lithium carbonate.

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TABLE 2

U.S. EXPORTS OF LITHIUM CHEMICALS, BY COMPOUND AND COUNTRY[1]

Compound and country	2004 Gross weight (metric tons)	2004 Value[2] (thousands)	2005 Gross weight (metric tons)	2005 Value[2] (thousands)
Lithium carbonate:				
Brazil	--	--	77	$1,480
Canada	126	$451	60	219
China	771	2,750	797	2,930
Germany	795	2,380	1,030	2,840
India	63	169	49	182
Japan	634	2,280	1,170	3,100
Korea, Republic of	329	874	38	139
Netherlands	105	378	169	430
Thailand	--	--	148	561
United Kingdom	177	743	242	651
Vietnam	--	--	54	147
Other	168 r	561 r	123	404
Total	3,170	10,600	3,960	13,100
Lithium carbonate, U.S.P.:[3]				
Australia	6	18	51	155
China	668	1,210	144	319
United Kingdom	56	103	21	36
Other	14 r	287 r	17	131
Total	738	1,600	233	641
Lithium hydroxide:				
Argentina	166	642	133	602
Australia	226	810	153	511
Belgium	410	1,260	179	514
Canada	150	609	156	655
China	40	100	180	645
Egypt	83	240	34	128
Germany	701	1,930	931	2,540
India	505	1,430	399	1,580
Japan	1,200	4,570	1,310	5,500
Korea, Republic of	278	1,010	262	1,120
Mexico	190	676	171	626
Netherlands	160	423	210	524
New Zealand	123	762	--	--
Russia	572	1,820	523	1,370
Singapore	107	317	114	454
South Africa	119	325	84	591
Sweden	56	132	95	234
Taiwan	57	272	17	58
Thailand	181	488	215	682
Ukraine	34	92	80	272
United Kingdom	118	651	89	257
Other	310 r	1,480 r	290	1,230
Total	5,780	20,000	5,620	20,100

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship values.

[3]Pharmaceutical-grade lithium carbonate. USP, U.S. Pharmacopeia.

Source: U.S. Census Bureau.

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TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF LITHIUM CHEMICALS BY COMPOUND AND COUNTRY[1]

Compound and country	2004 Gross weight (metric tons)	2004 Value[2] (thousands)	2005 Gross weight (metric tons)	2005 Value[2] (thousands)
Lithium carbonate:				
Argentina	4,850	$11,200	4,630	$9,600
Chile	10,500	15,200	14,300	17,700
Other	47	165	39	146
Total	15,400	26,500	18,900	27,500
Lithium hydroxide:				
Chile	--	--	54	172
China	16	38	1	10
Norway	27	45	48	93
United Kingdom	11	59	13	76
Other	10 r	91 r	8	102
Total	64	233	124	453

rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Customs value.

Source: U.S. Census Bureau.

TABLE 4

LITHIUM MINERALS AND BRINE: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005
Argentina:[4]					
Lithium carbonate	-- [5]	906 [5]	2,850	4,970 [5]	5,000
Lithium chloride	4,512 [5]	4,729 [5]	4,700	6,303 [5]	6,300
Australia, spodumene	79,859 [5]	79,085 [5]	124,410 [5]	118,451 r, 5	120,000
Brazil, concentrates	9,084 [5]	12,046 [5]	12,100	12,100	12,100
Canada, spodumene[6]	22,500	22,500	22,500	22,500	22,500
Chile, carbonate from subsurface brine	31,320 [5]	35,242 [5]	41,667 [5]	43,971 r, 5	44,000
China, carbonate	13,000	13,000	13,500	14,000	15,000
Portugal, lepidolite	11,571 [5]	16,325 [5]	16,000	16,000	16,000
Russia, minerals not specified[7]	2,000	2,000	2,000	2,200	2,200
United States, subsurface brine	W	W	W	W	W
Zimbabwe, amblygonite, eucryptite, lepidolite, petalite, and spodumene	36,103 [5]	33,172 [5]	12,131 [5]	13,710 r, 5	13,000

rRevised. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Table includes data available through March 28, 2006.

[2]Estimated data are rounded to no more than three significant digits.

[3]In addition to the countries listed, other nations may produce small quantities of lithium minerals, but output is not reported, and no valid basis is available for estimating production levels.

[4]New information was available from Argentine sources, prompting major revisions in how lithium production was reported.

[5]Reported figure.

[6]Based on all Canada's spodumene concentrates (Tantalum Mining Corp. of Canada Ltd.'s Tanco property).

[7]Lithium contained in concentrates and brine. These estimates denote only an approximate order of magnitude; no basis for more exact estimates is available. Other countries from the Commonwealth of Independent States, including Uzbekistan, could have produced or could be producing lithium, but information is not available for estimating production levels.

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MAGNESIUM

By Deborah A. Kramer

Domestic survey data and tables were prepared by Elena M. Lita, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Primary magnesium was produced by one company in the United States, and much of the U.S. demand was met by imports. Canada, Israel, and Russia were the principal sources of imported magnesium. Diecasting, aluminum alloying, and iron and steel desulfurization, in descending order, were the principal end-use applications for magnesium in the United States in 2005. China continued to dominate world production of primary magnesium, accounting for 75% of the total.

Legislation and Government Programs

Final antidumping duty orders on magnesium from China and Russia were published in April. For China, the final duties for magnesium alloy were 49.66% ad valorem for Tianjin Magnesium International Co. and Beijing Guangling Jinghua Science & Technology Co. Ltd. and 141.49% ad valorem for the China-wide rate. Magnesium covered under this order is classified under Harmonized Tariff Schedule (HTS) codes 8104.19.00 and 8104.30.00. The U.S. International Trade Commission (ITC) also determined that critical circumstances did not exist. As a result of this determination, antidumping duties were assessed on any material that entered the United States from China after October 4, 2004, which was the date that the preliminary duties were published. Material that entered between July 6, 2004, and October 4, 2004, was not subject to antidumping duties because of the negative critical circumstances finding (U.S. Department of Commerce, International Trade Administration, 2005b). An antidumping duty order was established on magnesium ingot from China in 1995 (108.26% ad valorem), and a separate antidumping duty order was established on granular magnesium from China in 2001 (24.67% and 305.56% ad valorem).

For Russia, the antidumping duties were 21.71% ad valorem for JSC Avisma Titanium-Magnesium Works, 18.65% ad valorem for Solikamsk Magnesium Works, and 21.01% for all others. The material covered under this order is classifiable under HTS codes 8104.11.00, 8104.19.00, 8104.30.00, and 8104.90.00 (U.S. Department of Commerce, International Trade Administration, 2005c).

In May, JSC Avisma filed an appeal of the ITC ruling that resulted in antidumping duties being established for magnesium imported from Russia with the U.S. Court of International Trade. In addition, one of the leading U.S. consumers of magnesium and a former U.S. magnesium producer, Alcoa Inc., filed a similar appeal, but Alcoa's appeal was directed against antidumping duties on magnesium imported from China (Brooks, 2005a).

In August, U.S. Magnesium LLC filed a "scope ruling request" with the U.S. Department of Commerce, International Trade Administration (ITA) alleging that Timminco Ltd. of Canada and Pechiney of France evaded United States antidumping duties by remelting ingots or pure magnesium pieces from China and Russia and exporting them to the United States as Canadian- or French-origin magnesium. Although Timminco and Pechiney were targeted by the filing, the scope was not limited to these two firms; it would apply to any company that had been importing Chinese- or Russian-origin magnesium that had been slightly modified (Peterson and McBeth, 2005).

The ITC also began a second 5-year review of antidumping duties on imports of pure magnesium from China. (A duty of 305.56% ad valorem had been established in 1995, except for one company for which the duty was 24.67% ad valorem.) A continuation of the antidumping duties was established after the first 5-year review in 2000 (U.S. International Trade Commission, 2005b).

Final countervailing duty determinations for calendar year 2003 for pure and alloy magnesium from Canada were announced in September 2005 by the ITA. For pure magnesium, the duty was 1.21% ad valorem for Norsk Hydro Canada Inc., and for alloy magnesium, the rates were 1.21% ad valorem for Norsk Hydro Canada and 5.40% ad valorem for Magnola Metallurgy Inc. (U.S. Department of Commerce, International Trade Administration, 2005d). In July, the ITC began its second 5-year review of countervailing duties on pure and alloy magnesium imported into the United States from Canada. The original duties were established in 1992, and a 5-year review was conducted in 2000 (U.S. International Trade Commission, 2005a).

The Government of Quebec and Magnola Metallurgy had appealed the ITA's decision on countervailing duties on magnesium to a North American Free-Trade Agreement binational panel. (A 7% ad valorem countervailing duty for alloy magnesium from Magnola Metallurgy was originally established in a new shipper review in 2003.) The binational panel upheld the ITA's original determination (U.S. Department of Commerce, International Trade Administration, 2005a).

Production

U.S. Magnesium Corp. announced that it would delay the startup of its planned expansion of 11,000 metric tons per year (t/yr). The company cited unfavorable market conditions that did not exist when the expansion plans were announced in 2004 as the main reason for its decision to delay the expansion. U.S. Magnesium did not announce a new date to bring the additional capacity online (Blamey and McBeth, 2005).

Environment

The cover gas sulfur hexafluoride (SF_6) that is used to protect molten magnesium from oxidation has been implicated as a potential factor in global warming. Although studies on its effect continue, its long atmospheric life (about 3,000 years) and high potential as a greenhouse gas (23,900 times the global warming potential of carbon dioxide) has resulted in a call for voluntary

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reductions in its emissions. In 1999, the U.S. magnesium industry, the International Magnesium Association, and the U.S. Environmental Protection Agency (EPA) began a voluntary partnership to understand and reduce emissions of SF_6. The major processes that require SF_6 melt protection are primary production; secondary production; die, permanent mold, and sand casting; wrought products; and anode production. According to the EPA, emissions from primary magnesium production and magnesium casting have halved between 1990 and 2004, and emissions in 2004 were 10% lower than those in 2003 despite processing additional magnesium. The most significant decrease has taken place since 1999, mainly because of a decline in the quantity of magnesium diecast and the closure of a U.S. primary magnesium production facility (U.S. Environmental Protection Agency, 2006§[1]).

In May, the U.S. Department of Justice, acting at the request of the EPA, filed a suit alleging that waste and dust from U.S. Magnesium's plant had elevated levels of polychlorinated biphenyls (PCBs). The PCB levels were estimated to be as high as 600 parts per million (ppm). PCB wastes are generally regulated for disposal under the Toxic Substance Control Act at concentrations greater than 50 ppm (Brooks, 2005b). U.S. Magnesium was already involved in a lawsuit that was brought in 2001 regarding dioxin releases at the plant.

Consumption

Data for magnesium metal are collected from two voluntary surveys of U.S. operations by the U.S. Geological Survey. Of the 80 companies canvassed for magnesium consumption data, 55% responded, representing 71% of the magnesium-base scrap consumption listed in table 2 and the primary magnesium consumption listed in table 3. Data for the 36 nonrespondents were estimated on the basis of prior-year consumption levels and other factors.

Reported primary magnesium consumption in 2005 was slightly lower than that in 2004 (table 3). Consumption of primary magnesium for diecasting applications increased by 8% from that in 2004. Diecasting remained the leading use for primary magnesium, accounting for 52% of the total, followed by aluminum alloying with 30% and iron and steel desulfurization with 7%.

On January 14, a fire started at a warehouse at the Advanced Magnesium Alloys Corp. (AMACOR) magnesium recycling plant in Anderson, IN, destroying about 25% of the facility. After an investigation by local, State, and Federal investigators, it was determined that the fire was intentionally set, and a reward was offered for information leading to the arson suspect (McCann, 2005; McFeely, 2005§). AMACOR restarted production at its plant at the end of May. A former employee was arrested and charged with arson (Platts Metals Week, 2005a).

A fire broke out on August 7 at Remacor Inc.'s magnesium grinding plant in West Pittsburgh, PA. Remacor produced magnesium-base desulfurization reagents for the iron and steel industry. Several drums of magnesium stored in one of the manufacturing buildings caught fire and exploded, and the fire spread to several smaller buildings at the site. The fire was allowed to burn until it burned out, which took several days. The cause of the fire was not determined (Lash, 2005§).

A new firm, MagPro LLC, planned to begin a magnesium recycling operation in 2006 in Camden, TN. One of the owners of the company was the former owner of bankrupt Halaco Engineering Inc., a magnesium recycler in Oxnard, CA, that closed in 2004 (Platts Metals Week, 2005c).

Stocks

Producers' yearend 2005 stocks of primary magnesium increased from those at yearend 2004; producer stock data were withheld to avoid disclosing company proprietary data. Consumer stocks of primary and alloy magnesium were 5,800 metric tons (t) at yearend 2005, a 28% decrease from the yearend 2004 level of 8,020 t (revised). Secondary magnesium stocks of 2,270 t at yearend 2005 were essentially the same as those at yearend 2004 of 2,260 t.

Prices

With the exception of a slight increase at the beginning of the year in anticipation of antidumping duties being established for magnesium imported from China and Russia, United States magnesium prices fell throughout 2005. The yearend 2005 U.S. magnesium price range was 30 to 40 cents per pound lower than that at yearend 2004 (table 4). Several reasons were suggested for the downturn in prices, particularly in the latter part of the year. Oversupply of magnesium, particularly from Russian producers, was cited as one reason for the drop in prices. Competition from recycled magnesium, which has a lower price, was cited as another reason. In addition, the phasing out of one of General Motors Corp.'s (GM) most comprehensive truck and sport utility vehicle redesign programs, which had been incorporating magnesium parts, contributed to the price decline (McBeth, 2005).

Contract prices among the magnesium producers and large consuming companies for 2006 were reported to be between $1.25 and $1.32 per pound, which was less than the 2005 contract level of about $1.40 to $1.50 per pound (Carroll, 2005).

Foreign Trade

Total magnesium exports for 2005 were about 18% less than those in 2004 (table 5). Canada (63%) and Mexico (19%) were the principal destinations. Imports for consumption in 2005 were 14% lower than those in 2004, reflecting a sharp decline in imports from China because of the antidumping duties assessed (table 6). China's share of total United States imports fell to 2% in 2005 from 19% in 2004. Of the total quantity of magnesium imported into the United States, Canada (46%), Israel (17%), and Russia (15%) were the principal sources in 2005. Nearly one-half the magnesium imported in 2005 was as alloy, and about one-third was in the form of pure metal. Canada supplied 61% of the magnesium alloy imports, and Russia and Israel together provided 72% of the pure magnesium imports in 2005.

World Review

Australia.—Despite the competition from magnesium produced in China, three companies were in the preliminary stages of initiating magnesium metal production in Australia,

[1]References that include a section mark (§) are found in the Internet References Cited section.

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attempting to revive plants that were originally proposed in the late 1990s. All the companies were seeking additional financing before proceeding with definitive production plans.

A new Australian company, Minemakers Australia NL, agreed to acquire the Lyons River and Arthur River, Tasmania, magnesite deposits that were owned by Crest Magnesium NL (now Australian Ethanol Ltd.). Australian Ethanol holds the deposits under its Tasmania Magnesite NL subsidiary. Plans to construct a 95,000-t/yr magnesium plant were shelved in 2001. Minemakers Australia would like to use the carbothermic technology that was being developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to recover magnesium, but this process has not been commercialized yet. In addition, Minemakers Australia was investigating the possibility of a 500,000-t/yr magnesia plant using the magnesite resources as a raw material. This would generate cash to develop the magnesium metal project (Forster, 2005).

Korab Resources Ltd. was investigating magnesium recovery from the Batchelor magnesite deposit in New South Wales. The project was a joint venture with New World Alloys Ltd. (formerly Mt. Grace Resources Ltd.), which had originally tried to develop a magnesium metal production plant from the deposit in 1999. The resource at the deposit was estimated to be 16.6 million metric tons containing 43% magnesium (Korab Resources Ltd., 2005§).

International Minerals Corp. Pty. Ltd. (Imcor) was investigating magnesium recovery from a waste silica-magnesia tailings pile in New South Wales. This was the same project that Pacific Magnesium Ltd. (formerly Golden Triangle Resources Ltd.) had been trying to develop since 1998. Pacific Magnesium was a shareholder in Imcor. Imcor planned to use Russian technology to recover the magnesium and produce silica as a coproduct. The company was seeking funding for detailed test work and a feasibility study that was scheduled to be completed in 2006 (Magnesium.com, 2005c§).

Brazil.—In October, the Brazilian Government expanded its antidumping duties on magnesium imported from China. In 2004, the country had imposed antidumping duties on imports with a magnesium content of 99.8% or greater. A new resolution imposed a duty of $1.18 per kilogram on imports from China with a magnesium content less than 99.8%. This duty will be in effect until October 2009 (Magnesium.com, 2005a§).

Canada.—Hydro Magnesium Inc. announced that it would increase production capacity at its magnesium plant in Becancour, Quebec, by 7,000 t/yr, with construction beginning in the first quarter of 2005. The company will improve its dehydration process and add four electrolytic cells to bring the total capacity at the plant to 58,000 t/yr by the third quarter of 2006 (Hydro Magnesium Inc., 2005b§).

On June 30, Falconbridge Ltd. and Noranda Inc. completed their merger. The merged company will continue to operate under the name Falconbridge Ltd. (Falconbridge Ltd., 2005b§). Noranda's 80% ownership of the closed 63,000-t/yr Magnola magnesium plant in Quebec was transferred to Falconbridge with the merger. On October 11, however, Inco Ltd. announced a friendly takeover bid for all outstanding shares of Falconbridge. This acquisition was pending at yearend (Falconbridge Ltd., 2005a§).

Leader Mining International Inc. established a wholly owned subsidiary, North Pacific Alloys Ltd. (NPAL), to conduct activities related to the company's Cogburn Magnesium Project. The Cogburn project was designed to extract magnesium from a magnesium silicate deposit in British Columbia. NPAL signed a 15-year operating agreement with Emil Anderson Construction Inc. for quarrying, ore transportation, and residue management of the magnesium silicate deposit. NPAL also signed an agreement with BC Hydro for providing 250 megawatts of electrical energy capacity to the project. The company's 2003 feasibility study for a 150,000-t/yr magnesium plant determined that the project was technically feasible and economically viable at a magnesium price of $1.27 per pound (Leader Mining International Inc., 2005§).

Automotive component supplier Magna International Inc. (Aurora, Ontario, Canada) expanded its business to include magnesium Thixomolding® and formed a special division dedicated to the process. Magna modified an injection molding machine from Husky Injection Molding Systems Inc. for the Thixomolding® process because it anticipated processing components with 2- to 3-millimeter wall thickness. Magna was awarded a contract from its subsidiary Intier Automotive Inc. for an integrated bracket for a closure (Metals Place, 2005§). Magna also purchased New Venture Gear Inc. from DaimlerChrysler Corp. in September 2004. New Venture Gear was a leading supplier of magnesium transfer cases in North America.

China.—China's National Bureau of Statistics reported that the country produced about 469,000 t of pure magnesium in 2005, an 8% increase from that in 2004. Exports of pure magnesium totaled 182,000 t, and exports of magnesium alloys were 93,000 t (Beijing Antaike Information Development Co., Ltd., 2006).

Forty small magnesium plants reportedly closed in the second quarter because of falling prices and environmental concerns. Each of the closed plants was estimated to have a capacity less than 1,000 t/yr of magnesium ingot. The China Magnesium Association expected that an additional 40 plants would be closed by the end of 2005. In addition, some of the larger firms have delayed expansion plans because of low magnesium prices (Mok, 2005).

Minhe Magnesium Co. announced that it shelved plans to expand magnesium alloy production at its facility in Qinghai Province. The company originally had planned to increase alloy capacity to 20,000 t/yr by mid-2005 from 4,000 t/yr, but because of unfavorable market conditions and weak prices, the expansion was delayed indefinitely (Platts Metals Week, 2005e).

In Inner Mongolia, Weixin Magnesium Co. Ltd. began construction of a 20,000-t/yr magnesium facility in March in the Urad Front Banner industrial zone. The plant, which will recover magnesium by the Pidgeon process, was scheduled to be completed by the end of 2005 (Beijing Antaike Information Development Co., Ltd., 2005).

Five new magnesium plants were scheduled to come onstream in 2005 (Interfax China Ltd., 2005). In Shanxi Province, Meijing Group Magnesium Industry Co. Ltd. opened a 10,000-t/yr primary magnesium plant in August, and Datuhe Magnesium Plant opened at 10,000-t/yr plant in March. Meijing was scheduled to add 10,000 t/yr of capacity in 2006, and Datuhe was scheduled to increase its capacity by 5,000 t/yr in 2006. In Inner Mongolia, Zhongrun Magnesium Co. Ltd. opened a 10,000-t/yr primary magnesium plant in December, with a capacity increase of 10,000 t/yr scheduled to be added in 2006. In Qinghai Province, Fengrui Magnesium Co. Ltd. opened a 4,000-t/yr primary magnesium plant in October, and Qinghai Drive Machine Manufacturing Co. Ltd. opened a 3,500-t/yr plant in July. Both companies were expected to increase plant capacity in 2006—Fengrui by 6,000 t/yr and Qinghai by 16,500 t/yr

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Hydro Magnesium increased its magnesium alloy remelting and recycling capacity to 15,000 t/yr at its plant in Xi'an in August. The plant was originally opened in 2002 with a capacity of 10,000 t/yr, producing AZ- and AM-series alloys from remelted pure magnesium from China (Platts Metals Week, 2005b).

In September, Meridian Technologies Inc. opened a new magnesium diecasting plant named Shanghai Meridian Magnesium Products Co. Ltd. in Shanghai. The new facility, with a capacity of 3,500 t/yr, will produce transmission cases and covers, steering column housings and supports, seat frames, instrument panel reinforcements, and other parts for domestic consumption and export. The plant's customers include Shanghai General Motors Co. Ltd., Shanghai Volkswagen Co. Ltd., DaimlerChrysler AG, and Delphi Corp. (Meridian Technologies Inc., 2005§).

Beginning on January 1, 2006, China will reduce the export tax rebates on many of its commodities including magnesium metal. The Government announced that it would cut the magnesium export rebate to 5% from 13% in an attempt to control exports. Analysts expected that prices for magnesium exports from China would increase in response to the rebate cut (Mok and McBeth, 2005).

Congo (Brazzaville).—MagIndustries Corp. inaugurated its first commercial-scale brine well in October near Point-Noire. The brine mine field initially will include five commercial-scale production wells within a 5-square-kilometer area near the village of Mengo. Each well will be completed to a target depth of about 600 meters where it will intersect the carnallite mineralization. After additional plants are constructed, the brine solution initially will be sent to a plant for the extraction of potassium salts, which will be upgraded into several grades of potash fertilizer. After removing the potassium, the magnesium-enriched brine will be sent to the company's proposed 60,000-t/yr magnesium smelter, for which construction was scheduled to begin in 2007. A final bankable feasibility study for a 40,000-t/yr potash plant was scheduled for completion in the second quarter of 2006 (MagIndustries Corp., 2005§).

Egypt.—During the second quarter of 2005, Egyptian Magnesium Co. (EMAG) [jointly owned by Magnesium International Ltd. (MIL) and Amiral Overseas Magnesium Ltd.] decided to base its bankable feasibility study on magnesite feedstock from Myrtle Springs, South Australia. EMAG, however, had been evaluating four additional deposits—two each in Saudi Arabia and Egypt. The principal deposit that EMAG was investigating is the Sul Hamed deposit in southern Egypt, where a small magnesite mining operation already exists. The deposit is held by El Nasr Mining Co. (a wholly owned subsidiary of the Egyptian Government). EMAG planned to negotiate an agreement with El Nasr to complete a resource evaluation and potential mining arrangements. Parallel evaluation of the other deposits, owned by Ma'aden in Saudi Arabia and El Nasr in Egypt, was expected to continue in the next two quarters (Platts Metals Week, 2005d).

EMAG expected that the total construction cost of the first module (43,000 t/yr) of its proposed 88,000-t/yr magnesium plant in Port Sokhna, Egypt, will be higher than had been forecast in the company's internal feasibility study. EMAG cited the high level of global demand for equipment and services, high raw material prices, including steel and copper, both of which are major components, and the relatively high European content of some materials for the project as reasons for the high construction costs. Because of the higher than anticipated costs, EMAG planned to delay construction until it can reduce capital costs. In addition, funding for EMAG will need to be resolved between MIL and Amiral and before the project progresses further (Magnesium International Ltd., 2005§).

MIL also signed an exclusive option to license CSIRO's magnesium sheet production process. The CSIRO technology is based on the application of the twin roll casting technique, which is used extensively in the aluminum industry, to the production of magnesium alloy sheet. Magnesium alloy strip can be produced directly from the melt with a thickness at or close to the final required shape, thereby reducing operational costs (Magnesium.com, 2005b§).

Netherlands.—United States-based Aleris International Inc. purchased the bankrupt Dutch firm Remag Alloys BV Delfzijl. The Dutch firm, which operated a 10,000-t/yr magnesium recycling facility in Delfzijl, filed for bankruptcy in June because of falling magnesium prices and competition from Chinese magnesium. Remag Alloys had been operating only since November 2003 and produced recycled magnesium mainly for the European automotive market. The plant restarted in November (Mason, 2005).

Russia.—RUSAL Ltd. announced that it would construct a 40,000-t/yr magnesium plant in the Volgograd region using locally mined bischofite as the raw material. The project was in the early planning stages (Magnesium.com, 2005d§).

Ukraine.—After Kalush Magniy was privatized in 2004, a $25 million investment to reconstruct the plant began, and production was restarted in January 2005. The plant had been closed since the late 1990s. Kalush expected to produce 6,000 t of magnesium in 2005, with plant capacity expanding to 10,000 t/yr in 2006 and 20,000 t/yr by 2007 (Kalush Magniy, undated §).

Current Research and Technology

In July, DaimlerChrysler, Ford Motor Co., and GM, as members of the United States Council for Automotive Research (USCAR), signed cooperative research agreements with the U.S. Department of Energy (DOE) to support continued research and development in the areas of lightweight materials and advanced battery technologies for vehicles. The agreements, which included DOE funding and industry cost share, when combined with a $70 million United States Automotive Materials Partnership agreement for lightweight, high-strength materials research, (initially announced in May), represented a total investment potential of $195 million during the next 5 years (United States Council for Automotive Research, 2005b§). As part of USCAR's FreedomCAR initiative, a number of research activities were underway to develop approaches for producing magnesium sheet at the volume and cost levels demanded by automotive applications. In particular, the economics associated with producing magnesium sheet at the volume and cost levels demanded by automotive applications are unclear. As such, in 2005, the Aluminum Consultants Group, in conjunction with Pacific Northwest National Laboratory, prepared a technical cost model for magnesium sheet production alternatives. In addition, the Structural Cast Magnesium Development Project focused on resolving critical issues that previously limited the large-scale application of magnesium castings in automotive components. Major accomplishments in 2005 included successful validation of a magnesium front engine cradle in a 2006 production vehicle (Chevrolet Corvette model). This resulted in a 34% weight savings compared with the 2005 production aluminum engine cradle (United States Council for Automotive Research, 2005a§).

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A team of research engineers from CSIRO developed a new permanent-mold magnesium casting technology called T-Mag. This technology can produce magnesium alloy castings that are essentially free of the porosity that has restricted the use of magnesium in the past. T-Mag has several advantages over traditional casting technologies, such as high-pressure casting. For example, with current casting technology 6 to 7 kilograms (kg) of metal is needed to produce a 3.5-kg casting. T-Mag requires only 3.7 kg of alloy for the same weight casting. The T-Mag permanent-mold casting process requires neither high pressure nor a vacuum to fill the die, which fills smoothly from the bottom. This minimizes air entrapment and oxidation and produces castings that are virtually free of defects. T-Mag combines melting and casting in a single unit that is hermetically sealed to protect the magnesium from oxidation and to minimize gas usage. Using the T-Mag process, CSIRO scientists have cast lightweight magnesium alloy engine blocks that are only two-thirds the weight of current aluminum alloy blocks. The new process also may enable casting of magnesium alloy wheels, powertrain components, and other load-critical applications, which are not economically feasible with current casting technologies (Commonwealth Scientific and Industrial Research Organisation, 2005§).

Engineers at BMW AG manufactured a cast magnesium water-cooled engine block. Because magnesium alloys cannot be used as material for cylinder liners, aluminum is used and integrated into the magnesium housing. Magnesium alloy $MgAl_6Sr_2$ is used for the block jacket, and the insert section consists of aluminum alloy $AlSi_{17}Cu_4Mg$. By replacing gray iron with aluminum, the weight was reduced by almost 30%. By using magnesium, the total weight reduction achieved, when compared with the original gray iron product, was almost 50%. The composite block has been on the market in the BMW 630i coupe since autumn 2004. BMW has the capacity to produce more than 500,000 6-cylinder composite blocks per year (Hydro Magnesium Inc., 2005a§).

Magnesium Elektron Ltd. announced that it developed a new wrought alloy, ELEKTRON® 675, which it claims is the world's strongest magnesium alloy at temperatures above 100° C. Applications were expected to be within the temperature range of 100° to 300° C across a broad range of markets, including aerospace, defense, motorsport, specialized automotive, and space. The new alloy's yield and tensile strengths were greater than those of wrought 2000 and 7000 series aluminum at temperatures above 100° C. At 200° C, the yield strength is more than 100% stronger than 2024 series of aluminum, and more than 200% stronger than 7075 series aluminum, both of which are used in aerospace applications (Magnesium Elektron Ltd., 2005§).

Outlook

Although new primary magnesium plants were planned for Australia, Canada, Congo (Brazzaville), and Egypt, it is unlikely that any of these will be constructed in the near future, if at all. Most of the companies that were planning magnesium plant construction continued to seek financing from outside sources. Even if the new plants were constructed, magnesium produced at these plants would have to compete in the world market with low-cost magnesium produced in China.

In contrast with other nonferrous metals (such as aluminum, copper, lead, and zinc), for which prices had increased significantly beginning in 2004, magnesium prices fell during the same period. This potentially could allow magnesium to be price competitive with materials for applications in the automotive industry, making magnesium a more attractive choice in component applications. Although magnesium alloy diecastings might be substituted for aluminum alloys, such as A380, in vehicles during their production cycle, it is more likely that any change would happen when the models are redesigned. In addition, high gasoline prices have led to increased awareness of fuel economy and may result in increased consumer demand for lighter vehicles. Incorporating magnesium alloy components could help to meet this demand.

U.S. titanium sponge producers have added capacity in 2005 and planned to increase total U.S. capacity by nearly 17,000 t by 2008 (Allegheny Technologies Inc., 2006§). This would provide a larger market for magnesium metal, and although most magnesium is recycled by the titanium industry, new magnesium also would be required to replace losses in the sponge production process.

According to a paper presented by Dead Sea Magnesium Ltd. at the 2006 International Magnesium Association conference, the diecasting segment has become the major application for magnesium, representing 35% of total world consumption in 2005. An increase of 8% to 10% in consumption was projected for 2006. The prediction of increased magnesium use in automotive applications was based on the development of new applications in powertrains. Increased use of magnesium in electronics and consumer goods also was predicted for 2006. Consumption of magnesium as an alloying element in aluminum continued to increase in line with the growing demand for aluminum products. The aluminum segment represented about 35% of total consumption of magnesium, and growth of 4% to 5% was forecast in 2006. Use of magnesium in Europe and Asia was growing faster than in North America and South America combined (Shair, 2006).

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TABLE 1
SALIENT MAGNESIUM STATISTICS[1]

(Metric tons unless otherwise specified)

	2001	2002	2003	2004	2005
United States:					
Production:					
Primary magnesium	W	W	W	W	W
Secondary magnesium	65,800	73,600	70,100	72,000 r	72,800
Exports	19,600	25,400	20,400	11,800	9,650
Imports for consumption	68,500	88,000	83,400	98,700	84,700
Consumption, primary	95,700	102,000	103,000	101,000 r	100,000
Yearend stocks, producer	W	W	W	W	W
Price[2] dollars per pound	1.21-1.28	1.10-1.22	1.10-1.17	1.55-1.60	1.15-1.30
World, primary production	420,000 r	440,000 r	485,000 r	595,000 r	626,000 e

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits.

[2]Source: Platts Metals Week.

TABLE 2
MAGNESIUM RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY[1]

(Metric tons)

	2004	2005
KIND OF SCRAP		
New scrap:		
Magnesium-base	15,800	16,300
Aluminum-base	35,700 r	37,000
Total	51,500 r	53,300
Old scrap:		
Magnesium-base	822	807
Aluminum-base	19,700	18,600
Total	20,500	19,400
Grand total	72,000 r	72,800
FORM OF RECOVERY		
Magnesium alloy ingot[2]	W	W
Magnesium alloy castings	1,920	1,410
Magnesium alloy shapes	353	439
Aluminum alloys	55,700	56,100
Other[3]	14,100	14,800
Total	72,000 r	72,800

rRevised. W Withheld to avoid disclosing company proprietary data; included in "Other."

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes secondary magnesium content of both secondary and primary alloy ingot.

[3]Includes chemical and other dissipative uses, cathodic protection, and data indicated by symbol W.

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TABLE 3
U.S. CONSUMPTION OF PRIMARY MAGNESIUM, BY USE[1]

(Metric tons)

Use	2004	2005
For structural products:		
Castings:		
Die	48,100 r	51,900
Permanent mold	138 r	112
Sand	391	412
Wrought products[2]	2,240	2,880
Total	50,900 r	55,300
For distributive or sacrificial purposes:		
Aluminum alloys	33,900	30,300
Cathodic protection (anodes)	3,520	3,020
Iron and steel desulfurization	8,360	7,410
Reducing agent for titanium, zirconium, hafnium, uranium, beryllium	934	812
Other[3]	3,580	3,540
Total	50,300	45,100
Grand total	101,000 r	100,000

rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes sheet and plate and forgings.

[3]Includes chemicals; nodular iron; and scavenger, deoxidizer, and powder.

TABLE 4
YEAREND MAGNESIUM PRICES

Source		2004	2005
Platts Metals Week:			
U.S. spot Western	dollars per pound	1.55-1.60	1.15-1.30
U.S. spot dealer import	do.	1.40-1.55	1.14-1.24
European free market	dollars per metric ton	1,850-1,900	1,560-1,700
Metal Bulletin:			
European free market	do.	1,890-1,940	1,590-1,600
China free market	do.	1,730-1,750	1,500-1,520

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TABLE 5
U.S. EXPORTS OF MAGNESIUM, BY COUNTRY[1]

Country	Waste and scrap		Metal		Alloys, gross weight		Powder, sheets, tubing, ribbons, wire, other forms, gross weight	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
2004:								
Brazil	--	--	--	--	2	$36	5	$94
Canada	4,450	$10,400	1,730	$3,690	1,210	3,990	842	4,600
Mexico	151	427	--	--	158	782	2,020	6,980
United Kingdom	--	--	10	28	23	143	359	7,950
Other[r]	196	511	22	104	355	2,830	303	6,200
Total	4,790	11,300	1,760	3,830	1,750	7,780	3,530	25,800
2005:								
Brazil	--	--	--	--	420	1,010	9	246
Canada	4,790	10,800	701	2,340	205	1,730	365	3,800
Mexico	458	1,280	13	45	302	849	1,070	4,760
United Kingdom	24	69	--	--	58	269	244	6,170
Other	360	895	18	87	214	2,020	396	7,460
Total	5,630	13,100	732	2,470	1,200	5,870	2,080	22,400

[r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF MAGNESIUM, BY COUNTRY[1]

Country	Waste and scrap		Metal		Alloys, magnesium content		Powder, sheets, tubing, ribbons, wire, other forms, magnesium content	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
2004:								
Canada	10,000	$15,600	1,850	$6,390	22,900	$69,600	892 [r]	$7,410
China	228	429	18	57	18,100	45,900	75	301
Israel	--	--	8,790	24,500	4,140	15,700	--	--
Russia	--	--	20,700	40,500	2,500	5,400	146	972
Other	1,420	1,580	2,890	6,820	3,850	15,200	64 [r]	1,500
Total	11,700	17,600	34,300	78,200	51,500	152,000	1,180 [r]	10,200
2005:								
Canada	8,910	12,400	4,810	15,000	24,500	83,200	833	7,280
China	693	995	19	32	693	2,310	26	276
Israel	--	--	9,040	29,700	5,560	23,300	--	--
Russia	--	--	11,800	27,400	768	1,710	143	599
Other	5,060	9,320	3,090	8,540	8,720	28,100	40	1,910
Total	14,700	22,700	28,700	80,700	40,300	139,000	1,040	10,100

[r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 7
WORLD ANNUAL PRIMARY MAGNESIUM
PRODUCTION CAPACITY, DECEMBER 31, 2005[1, 2]

(Metric tons)

Country	Capacity
Brazil	12,000
Canada	123,000 [3]
China	528,000
India	900
Israel	27,500
Kazakhstan	10,000
Russia	46,000
Serbia and Montenegro	5,000
Ukraine	15,000
United States	45,000
Total	812,000

[1]Includes capacity at operating plants as well as at plants on standby basis.

[2]Data are rounded to no more than three significant digits; may not add to total shown.

[3]Includes 63,000 metric tons per year of idle capacity.

TABLE 8
MAGNESIUM: PRIMARY WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005[e]
Brazil[e]	5,500	6,000	6,000	6,000	6,000
Canada[e, 3]	83,000	88,000	54,000	54,000	54,000
China[e]	200,000	250,000	340,000	442,000 [r]	470,000
France[e]	4,000	--	--	--	--
Israel	34,000 [e]	26,000 [r]	26,000 [r]	28,000	27,600 [4]
Kazakhstan[e]	16,000	18,000	14,000	18,000	20,000
Norway[e]	36,000	10,000	--	--	--
Russia[e, 3]	40,000 [r]	40,000 [r]	43,000 [r]	45,000 [r]	45,000
Serbia and Montenegro[e]	1,630 [4]	1,695 [4]	1,600	1,600	1,500
Ukraine[e]	3	3	3	3	2,000
United States	W	W	W	W	W
Total	420,000 [r]	440,000 [r]	485,000 [r]	595,000 [r]	626,000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 20, 2006.

[3]Includes secondary.

[4]Reported figure.

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MAGNESIUM COMPOUNDS

By Deborah A. Kramer

Domestic survey data and tables were prepared by Elena M. Lita, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

Domestic production of caustic-calcined magnesia and dead-burned magnesia in 2005 increased from those 2004, but imports continued to supply most of the U.S. demand for magnesia. Consumption of refractory magnesia increased by about 16% from that in 2004, with imports supplying a significant portion of the total. Caustic-calcined magnesia consumption increased slightly, with imports supplying about 50% of total U.S. demand. Production of magnesium hydroxide increased; much of the increase was in response to increased consumption of magnesium hydroxide in environmental applications.

About 52% of U.S. magnesium compounds production came from seawater and well and lake brines. The remainder was recovered from brucite, dolomite, magnesite, and olivine. About 60% of the total consumption of magnesium compounds was for refractory applications. The remaining 40% was used in agricultural, chemical, environmental, and other applications. China remained the dominant supplier of imports for refractory (dead-burned and fused) and caustic-calcined magnesias with 82% and 63%, respectively, of the totals.

Legislation and Government Programs

On September 7, 2 United States companies sued a group of 17 Chinese magnesite producers and exporters under Federal antitrust law in New Jersey District Court. The suit claimed that the Chinese companies had conspired to manipulate the price of magnesite and related exports to the United States and other countries, which violated fair trade laws of the United States (Doudou and Yi, 2005§[1]).

Production

Shipments of caustic-calcined magnesia, refractory magnesia, and magnesium hydroxide increased, and production of magnesium carbonate and magnesium sulfate fell (table 3). Increased use of magnesium hydroxide in environmental applications was partially responsible for the 28% increase in production of magnesium hydroxide.

Data for magnesium compounds were collected by the U.S. Geological Survey from one voluntary survey of U.S. operations. Of the 16 operations canvassed, 69% responded, representing 92% of the magnesium compounds shipped and used, including data for some compounds that were not reportable in table 3. Data for the five nonrespondents were estimated on the basis of prior-year consumption levels.

The largest capacity magnesite production facilities in the world are in China, North Korea, and Russia. Together, these three countries accounted for two-thirds of the world magnesite production capacity. Japan and the United States accounted for about one-half of the world's magnesium compounds production capacity from seawater or brines. Fused magnesia was produced in Australia, Brazil, Canada, China, Israel, Japan, the Republic of Korea, Mexico, Russia, the United Kingdom, and the United States. World production capacity was estimated to be about 650,000 metric tons per year (t/yr), including about 500,000 t/yr of capacity in China.

Fused magnesia was produced by two companies in the United States—Newminco Inc. with a plant in Midway, TN, and UCM Group PLC of the United Kingdom, which operated a plant in Cherokee, AL, through its Muscle Shoals Minerals Inc. subsidiary.

Norway is the world's principal producer and supplier of olivine. Other producers include Australia, Austria, Brazil, China, Denmark (Greenland), Italy, Japan, the Republic of Korea, Mexico, Spain, Taiwan, Turkey, and the United States. Rudi (2001) estimated that total world production of olivine averaged about 4 million metric tons per year (Mt/yr), with about 3.3 Mt/yr consumed in Europe. An additional 4 Mt/yr of dunite and serpentinite that is often commercially called olivine is produced. One company in the United States produced olivine—Olivine Corp., which operated one mine and processing plant in Washington.

In August, Great Salt Lake Minerals Corp. announced plans to increase its liquid magnesium chloride capacity in Utah by 70% and double its capacity to produce solid magnesium chloride by mid-2006. The company expected to invest $12 million during the next 2 years to expand its magnesium chloride evaporation ponds at Great Salt Lake, upgrade its production facility, and add rail infrastructure (Compass Minerals International, Inc., 2005§).

Consumption

In 2005, chemical intermediates were the largest tonnage end use for caustic-calcined magnesia, with 39% of the total. Environmental applications (water treatment and stack gas scrubbing, in descending order) were the second largest end use, with 28% of the total. The following categories, with the individual components in descending order of consumption in parentheses, were the other end-use sectors for caustic-calcined magnesia: agriculture (animal feed and fertilizers), 15%; construction (primarily oxychloride and oxysulfate cements), 8%; manufacturing (fluxes, rubber, and electrical), 6%; pharmaceuticals and nutrition, less than 1%; and unspecified uses, 4%.

Magnesium hydroxide was used mainly for water treatment, as a chemical intermediate, and in medicines and pharmaceuticals (uses are given in descending order of quantity). Smaller applications for magnesium hydroxide were in the construction industry, in rubber processing, and in pharmaceuticals. Magnesium sulfate was used mostly for chemical, fertilizer, pulp and paper, pharmaceutical, rubber, water treatment, construction, and cosmetics applications (in descending order of quantity).

[1]References that include a section mark (§) are found in the Internet References Cited section.

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Magnesium chloride was used mainly for ice control. Magnesium chloride brines were used for road dust and ice control.

Prices

Prices published in Chemical Market Reporter and Industrial Minerals at yearend 2005 for magnesium compounds and olivine did not change from those published at yearend 2004 (table 4).

Foreign Trade

Dead-burned magnesia exports in 2005 were 17% less than those in 2004 (table 5). Canada (83%) was the principal destination. Caustic-calcined magnesia exports increased by 32% from those in 2004. Venezuela (45%) and France (29%) were the main destinations.

Imports of dead-burned magnesia increased by about 14% from those in 2004, with imports from China representing 82% of the total (table 7). Imports of caustic-calcined magnesia were about 3% less than those in 2004. China (63%) and Canada (27%) were the primary sources.

Trade data for olivine are not available separately from the U.S. Census Bureau. The Journal of Commerce Port Import/Export Reporting Service (PIERS), however, provides data on material that travels by ship. U.S. exports of olivine in 2005 were 3,090 metric tons (t). Argentina (59%) and Mexico (35%) were the principal destinations. U.S. olivine imports were 147,000 t, 54% higher than those in 2004. Norway was the source of almost all (99.4%) United States olivine imports.

World Review

European Union.—On October 6, the European Commission (EC) imposed antidumping duties on imports of magnesia refractory bricks from China. The antidumping duties ranged from 8.1% to 39.9%, applicable to the net free-at-Community-frontier price, depending upon the exporting company. The duty affects bricks that contain at least 80% magnesium oxide. During the investigation period, the EC found that import quantities from China into the European Union had increased by about 150% and the import values had declined by 22% (Industrial Minerals, 2005c).

Australia.—Queensland Magnesia Pty. Ltd. (QMag) planned to spend about $4.9 million upgrading its Kunwarara magnesite mine near Marlborough in central Queensland. The initial expansion would create about 50 jobs; this announcement was the first stage of an overall planned expansion that could generate an additional 150 jobs. No details on the size of the expansion were available. QMag had the capacity to produce 110,000 t/yr each of caustic-calcined magnesia and dead-burned magnesia and 25,000 t/yr of fused magnesia (ABC News Online, 2005§).

Austria.—To meet growing global demand for high-purity magnesium hydroxide flame retardants, MAGNIFIN Magnesiaprodukte GmbH & Co. KG (the Albemarle Corp. and RHI Group joint-venture company) announced that it would double its 10,000-t/yr capacity at its Breitenau site in two stages. Completion was scheduled for 2006 (Albemarle Corp., 2005§).

Canada.—Baymag Inc. mothballed Plant 1 at its Exshaw, Alberta, magnesia operation in mid-2005, citing rising energy costs and increased maintenance as the principal reasons for the closure. Plant 1 included a 100,000-t/yr natural-gas-fired rotary kiln that was leased from Lafarge Group and had been operating since 1982. Baymag expected to continue to operate Plant 2, which includes a 50,000-t/yr vertical shaft kiln that was installed in 1997, to produce caustic-calcined magnesia. The company also had the capacity to produce 14,000 t/yr of fused magnesia from Plant 2 (Industrial Minerals, 2005a).

China.—The Chinese magnesite export syndicate that was formed in February 2004 fell apart less than 1 year after its formation. The syndicate was the fifth in a series of associations established to control pricing and export quantities of magnesite. Two of the reasons cited for the failure to establish an export syndicate were that the prices set by the association were too high and, as a result, too much of the export quota was left for sale at the end of the year (O'Driscoll, 2005).

China's Ministry of Commerce announced the export quota for calcined magnesia for 2006. The total was 1.36 million metric tons (Mt), a slight decrease from the 1.4 Mt offered in 2005.

Greenland.—The Seqi olivine mine was officially opened on August 11, and in December, the first shipment of 43,000 t of olivine arrived in Amsterdam, Netherlands, for processing and subsequent sale to the European market. Production capacity for the new mine was expected to reach 1.1 Mt/yr in 2006. Beginning in August 2006, olivine processing for steel applications was scheduled to take place in Greenland, and processing for refractory and foundry applications would take place in Europe. Minelco AB (the project owner) purchased Crew Development Corp.'s portion of the project in July, and the company planned to supply the North American market with olivine for trials beginning in January 2006. Minelco's captive consumption of olivine was estimated to be 300,000 t/yr, and the new mine will have enough capacity to supply the company as well as provide olivine for export (Industrial Minerals, 2006).

Jordan.—Because of technical problems with some plant equipment, the Jordan Magnesia Co. Ltd. (Jormag) magnesia plant remained closed throughout 2005. The plant had closed in December 2004 for scheduled maintenance, but did not reopen. In addition, the company's exclusive sales agent, Possehl S.A., withdrew from its agreement to represent Jormag for the sale of their products (Industrial Minerals, 2005h).

Russia.—Russian Mining Chemical Co. LLC announced that it would increase production capacity for brucite from its mine in the Jewish Autonomous Region to 80,000 to 100,000 t/yr in 2006 from 50,000 t/yr. This mine is the only producer of brucite in Russia and has supplied the country's needs for brucite as a flux component for metallurgy and for refractories. The company planned to upgrade its facilities to increase production of ground brucite for environmental and flame-retardant applications (Industrial Minerals, 2005e).

Serbia and Montenegro.—The Kosovo Trust Agency, which was established in 2002 to privatize dormant public companies, announced in September that the area's two magnesite mines, XIM Strezoc Magnesite Mine and Goleshi Magnesite Mine, were available for sale. The Strezoc Mine was estimated to contain between 4.5 and 5.5 Mt of magnesite, which included higher grade ore reserves of 1.5 to 1.7 Mt. The reserves at the Goleshi Mine were estimated to be 2.4 Mt of medium- to high-grade

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magnesite. Although both operations produced dead-burned and caustic-calcined magnesia prior to the Balkan conflict in the early 1990s, neither had been producing since the early 2000s. The first bids for the operations were due on January 18, 2006 (Industrial Minerals, 2005b; Kosovo Trust Agency, 2005§).

Turkey.—ŞETAT Madencilik Gıda Sanayi ve Ticaret A.Ş. (Setat Mining) began processing and test production at its new olivine mine in Orhaneli in September 2004, and commercial production began in 2005. The company's total production capacity at the mine was 400,000 t/yr, and the company produced products for slag conditioning and ballast (120,000 t/yr), steelmaking (100,000 t/yr), abrasives (85,000 t/yr), foundry sand (75,000 t/yr), and refractory (20,000 t/yr) applications for domestic and European markets. Setat Mining also planned to invest in an olivine pilot plant in the Isparta-Eğridir region where it has 2,000 hectares of mining concessions (Industrial Minerals, 2005g; ŞETAT Madencilik Gıda Sanayi ve Ticaret A.Ş., undated§).

In December 2004, Akdeniz Mineral Kaynaklari A.Ş acquired Comag Continental Madencilik Sanayii Tic. A.Ô.'s magnesite calcination and beneficiation plant in Kumbet and a beneficiation plant and a concession of 2,230 hectares in Erenkoy. During 2005, Akdeniz Mineral (a subsidiary of Grecian Magnesite S.A.) completed repairs to the Kumbet facility, which was expected to reopen in 2006 with a production capacity of 12,000 t/yr of caustic-calcined magnesia (Industrial Minerals, 2005f).

United Kingdom.—After nearly 70 years of production, CJC Chemicals & Magnesia Ltd., the sole magnesia producer in the United Kingdom, closed in June. It had the capacity to produce 7,000 t/yr of caustic-calcined magnesia and 20,000 t/yr of magnesium hydroxide from seawater. The plant had produced dead-burned magnesia from its startup in 1937 until 2002 (Industrial Minerals, 2005d).

Outlook

According to the International Iron and Steel Institute (2006§), world steel production in 2005 increased by 5.9% from that in 2004, with China as the leading producer. Production in China increased by almost 25% and represented nearly 31% of total world production. Because Chinese production was outstripping demand and the market was oversupplied, China's Government intended to close inefficient and uneconomic capacities and concentrate a greater share of output under the control of several large companies. Even if some operations are closed, China was expected to remain the world's dominant steel producer. Increased iron and steel production in China could lead to more internal consumption of refractories, which would mean that less material would be available for export. Because the United States has lost much of its refractory magnesia production capacity in recent years and China is the principal United States supplier, a shortage of supply in the United States is possible. China, however, has vast resources of magnesite, and could increase magnesite production capacity to meet its internal and export needs.

Caustic-calcined magnesia markets are fairly mature, but use of magnesium hydroxide for environmental applications is growing. Because of its superior properties, magnesium hydroxide is expected to continue to replace such material as lime and caustic soda in some environmental applications.

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TABLE 1
SALIENT MAGNESIUM COMPOUND STATISTICS[1]

(Thousand metric tons and thousand dollars)

	2001	2002	2003	2004	2005
United States:					
Caustic-calcined and specified magnesias:[2]					
Shipped by producers:[3]					
Quantity	136	127	154	132	137
Value	43,300	38,100	61,000	55,400	60,300
Exports[4]	4	6	4	4	5
Imports for consumption[4]	130	148	150	157	152
Refractory magnesia:					
Shipped by producers:[3]					
Quantity	213	123	84	W	W
Value	71,300	37,800	23,500	W	W
Exports	63	73	56	30	25
Imports for consumption	363	394	379	418	478
World, production of magnesite	11,100	13,600	14,000	14,700 r	14,300 e

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data.
[1]Data are rounded to no more than three significant digits.
[2]Excludes caustic-calcined magnesia used in the production of refractory magnesia.
[3]Includes magnesia used by producers.
[4]Caustic-calcined magnesia only.

TABLE 2
U.S. MAGNESIUM COMPOUND PRODUCERS, BY RAW MATERIAL SOURCE, LOCATION, AND PRODUCTION CAPACITY, IN 2005[1]

(Metric tons, MgO equivalent)

Raw material source and producing company	Location	Capacity	Products
Brucite, Applied Chemical Magnesias Corp.	Van Horn, TX, and Bullhead City, AZ	25,000	Magnesium hydroxide.
Magnesite, Premier Chemicals LLC	Gabbs, NV	140,000	Caustic-calcined magnesia.
Lake brines:			
Great Salt Lake Minerals Corp.	Ogden, UT	106,000	Magnesium chloride and magnesium chloride brines.
Intrepid Wendover-Potash LLC	Wendover, UT	45,000	Magnesium chloride brines.
Well brines:			
Martin Marietta Magnesia Specialties LLC[2]	Manistee, MI	297,000	Caustic-calcined magnesia, dead-burned magnesia, and magnesium hydroxide.
Rohm and Haas Co.	do.	25,000	Magnesium hydroxide and caustic-calcined magnesia.
Seawater:			
Premier Chemicals LLC	Port St. Joe, FL	107,000	Caustic-calcined magnesia and magnesium hydroxide.
South Bay Salt Works	Chula Vista, CA	3,000	Magnesium chloride brines.
SPI Pharma Inc.	Lewes, DE	5,000	Magnesium hydroxide.
Total		753,000	

[1]Data are rounded to no more than three significant digits; may not add to total shown.
[2]In addition to its Michigan plant, Martin Marietta owned a 15,000-metric-ton-per-year-capacity magnesium hydroxide plant in Lenoir City, TN, which used imported magnesite as a raw material.

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TABLE 3
U.S. MAGNESIUM COMPOUNDS SHIPPED AND USED[1]

	2004		2005	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Caustic-calcined and specified (USP and technical) magnesias[2]	132,000	$55,400	137,000	$60,300
Magnesium hydroxide [100% $Mg(OH)_2$][2]	113,000	60,700	145,000	70,700
Magnesium sulfate, anhydrous and hydrous	53,700	15,200	52,300	16,500
Precipitated magnesium carbonate[2]	105	475	--	--
Refractory magnesia	W	W	W	W

W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Data are rounded to no more than three significant digits.

[2]Excludes material produced as an intermediate step in the manufacture of other magnesium compounds.

TABLE 4
YEAREND MAGNESIUM COMPOUND PRICES

Material		2004	2005
Magnesia, dead-burned	per short ton	$365-375	$365-375
Magnesia, synthetic, technical, 98% MgO	do.	490	490
Magnesium chloride, hydrous, 99%, flake	do.	290	290
Magnesium chloride, anhydrous, 92%, flake or pebble	per pound	0.1275-0.15	0.1275-0.15
Magnesium hydroxide, powder, technical	do.	0.45	0.45
Magnesium hydroxide slurry, technical, 100% $Mg(OH)_2$	do.	238-250	238-250
Magnesium sulfate, technical (epsom salts)	do.	0.18-0.215	0.18-0.215
Olivine, aggregate, free on board plant or mine	per metric ton	50-78	50-78
Olivine, foundry grade, free on board plant or mine	do.	62-109	62-109

Sources: Chemical Market Reporter and Industrial Minerals.

TABLE 5
U.S. EXPORTS OF CRUDE AND PROCESSED MAGNESITE, BY COUNTRY[1]

	2004		2005	
Material and country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Caustic-calcined magnesia:				
France	1,300	$752	1,430	$846
Germany	412	230	412	246
Netherlands	1,330	696	475	280
Venezuela	--	--	2,200	869
Other	674	517	406	257
Total	3,720	2,200	4,920	2,500
Dead-burned and fused magnesia:				
Brazil	286	294	205	193
Canada	23,500	8,020	20,800	7,850
France	445	270	41	38
Germany	462	278	550	509
Korea, Republic of	417	267	19	12
Mexico	574	573	497	642
Netherlands	814	561	333	196
Taiwan	618	359	237	168
United Kingdom	577	5,240	307	315
Venezuela	612	215	605	243
Other	1,650	1,200	1,400	1,220
Total	29,900	17,300	24,900	11,400

See footnotes at end of table.

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TABLE 5—Continued

U.S. EXPORTS OF CRUDE AND PROCESSED MAGNESITE, BY COUNTRY[1]

Material and country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Other magnesia:				
Brazil	387	494	1,260	1,540
Canada	6,320	3,090	5,480	2,960
Germany	820	834	2,350	1,510
Hong Kong	393	426	496	456
Indonesia	1,240	734	142	92
Japan	3,020	2,530	247	372
Mexico	3,400	2,980	3,240	3,000
Taiwan	4,780	2,700	651	538
United Kingdom	834	1,010	766	757
Venezuela	34	65	878	278
Other	2,570 r	3,360 r	6,210	6,830
Total	23,400	17,700	21,700	18,300
Crude magnesite:				
Argentina	732	78	1,250	133
Australia	4,030	465	5,040	588
Canada	3,940	509	4,770	617
France	4,730	511	4,570	489
Germany	1,650	176	1,960	212
Mexico	598	63	474	53
Sweden	--	--	1,090	117
United Kingdom	97	10	1,120	120
Venezuela	2,710	320	--	--
Other	964	113	1,550	165
Total	19,500	2,250	21,800	2,490

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6

U.S. EXPORTS OF MAGNESIUM COMPOUNDS[1]

Material	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)	Principal destinations, 2005
Magnesium chloride, anhydrous and other	5,100	$3,390	6,060	$3,750	Canada, 83%.
Magnesium hydroxide and peroxide	15,700	10,100	13,500	11,100	Canada, 57%; United Kingdom, 12%.
Magnesium sulfate, natural kieserite and epsom salts	11,900	1,130	2,780	483	Canada, 100%.
Magnesium sulfate, other	8,450	3,520	10,300	4,190	Canada, 91%.

[1]Data are rounded to no more than three significant digits.

Source: U.S. Census Bureau.

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TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF CRUDE AND PROCESSED MAGNESITE, BY COUNTRY[1]

Material and country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Caustic-calcined magnesia:				
Australia	1,670	$597	160	$57
Brazil	3,000	296	5,800	638
Canada	55,500	9,300	40,900	7,390
China	96,400	11,300	96,300	13,700
Greece	--	--	3,000	759
Korea, Republic of	--	--	5,270	916
Other	830	671	677	439
Total	157,000	22,200	152,000	23,900
Dead-burned and fused magnesia:				
Australia	10,800	3,270	13,300	6,910
Austria	27,700	14,600	28,000	14,200
Brazil	6,000	770	--	--
China	341,000	71,000	390,000	82,900
Greece	2,650	500	6,050	1,290
Hong Kong	5,300	992	20,900	4,310
Israel	2,760	5,120	2,010	4,160
Japan	3,390	5,340	3,830	5,520
Korea, Republic of	2	10	6,200	1,380
Mexico	11,800	3,970	5,680	2,270
Netherlands	4,550	1,540	--	--
Other	2,120	1,590 r	1,860	909
Total	418,000	109,000	478,000	124,000
Other magnesia:				
Canada	1,900	428	1,100	297
China	3,160	1,480	2,690	1,690
Israel	859	1,430	442	648
Japan	1,760	3,090	1,300	2,430
Mexico	2,010	1,120	8,120	3,150
Netherlands	18	38	1,490	1,230
Slovakia	3,870	1,210	1,890	654
Other	2,080 r	2,010 r	1,260	1,230
Total	15,700	10,800	18,300	11,300
Crude magnesite:				
Brazil	541	200	920	241
Canada	6,180	404	238	15
China	6,100	618	5,310	297
Israel	81	24	2,360	450
Japan	2,320	500	4,330	887
Korea, Republic of	412	179	--	--
Other	272 r	54 r	1,840	373
Total	15,900	1,980	15,000	2,260

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF MAGNESIUM COMPOUNDS[1]

	2004		2005		
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Principal sources, 2005
Magnesium chloride, anhydrous and other	83,800	$15,200	72,900	$15,100	Israel, 86%; Netherlands, 12%.
Magnesium hydroxide and peroxide	6,390	10,800	6,240	12,100	Israel, 29%; Japan, 21%; Netherlands, 18%.
Magnesium sulfate, natural epsom salts	1,040	289	1,310	349	India, 66%; China, 24%.
Magnesium sulfate, natural kieserite	10,800	558	13,900	1,030	Germany, 100%.
Magnesium sulfate, other	30,100	13,700	24,500	6,140	Germany, 61%; Canada, 29%.

[1]Data are rounded to no more than three significant digits.

Source: U.S. Census Bureau.

TABLE 9
WORLD MAGNESIUM COMPOUNDS ANNUAL PRODUCTION CAPACITY, DECEMBER 31, 2005[1, 2]

(Thousand metric tons, MgO equivalent)

	Raw material				
	Magnesite		Seawater or brines		
Country	Caustic-calcined	Dead-burned	Caustic-calcined	Dead-burned	Total
Australia	82	108	--	--	190
Austria	197	268	--	--	465
Brazil	58	276	--	--	334
Canada	150	--	--	--	150
China	275	2,940	--	10	3,230
France	--	--	30	--	30
Greece	120	100	--	--	220
India	20	296	--	--	316
Iran	--	30	--	--	30
Ireland	--	--	--	90	90
Israel	--	--	10	60	70
Italy	25	--	--	--	25
Japan	--	--	50	250	300
Jordan	--	--	10	50	60
Korea, North	--	1,100	--	--	1,100
Korea, Republic of	--	--	--	40	40
Mexico	--	--	15	95	110
Netherlands	--	--	10	150	160
Poland	--	10	--	--	10
Russia	100	2,400	--	--	2,500
Serbia and Montenegro	40	160	--	--	200
Slovakia	--	465	--	--	465
South Africa	12	--	--	--	12
Spain	145	60	--	--	205
Turkey	15	404	--	--	419
Ukraine	--	120	20	80	220
United Kingdom	--	--	7	--	7
United States	140	--	201	195	536
Total	1,380	8,740	353	1,020	11,500

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes capacity at operating plants, as well as at plants on standby basis.

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TABLE 10

MAGNESITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005[e]
Australia	605,314	484,498	472,668	325,402	335,000
Austria, crude[e]	700,000	700,000	700,000	700,000	700,000
Brazil, beneficiated	265,749	302,230 [r]	306,444 [r]	366,174 [r]	370,000
Canada[e, 3]	180,000	180,000	180,000	180,000	180,000
China[e]	3,580,000	4,560,000	4,600,000	4,650,000	4,700,000
Colombia[e]	10,500	10,500	10,500	10,500	10,500
Greece, crude[e]	500,000	500,000	500,000	500,000	500,000
India[e]	370,000	380,000	380,000	370,000	360,000
Iran[4]	133,778	128,565	87,795 [r]	88,194 [r]	88,000
Korea, North[e]	1,000,000	1,000,000	1,000,000	1,200,000 [r]	1,200,000
Mexico	250	--	-- [e]	-- [e]	--
Pakistan[e]	4,200	4,000	4,200	4,200	4,400
Poland, concentrate	22,200	22,100	22,000	22,000 [e]	20,000
Russia[e]	1,000,000	1,000,000	1,200,000	1,200,000	1,100,000
Serbia and Montenegro, crude[e]	36,000 [5]	33,000	25,000	25,000	25,000
Slovakia, concentrate	961,000	929,630	993,900	995,000 [e]	1,000,000
South Africa	36,500	87,200	86,100	65,900 [r]	66,000
Spain, calcined[e]	260,000	250,000	250,000	250,000	250,000
Turkey, run-of-mine	1,450,031	3,044,440	3,224,278	3,732,952 [r]	3,400,000
United States	W	W	W	W	W
Zimbabwe	2,439	2,366	1,333	749	893 [5]
Total	11,100,000	13,600,000	14,000,000	14,700,000 [r]	14,300,000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Figures represent crude salable magnesite. In addition to the countries listed, Bulgaria produced magnesite, but output is not reported quantitatively and available information is inadequate for formulation of reliable estimates of output levels. Table includes data available through May 15, 2006.

[3]Magnesitic dolomite and brucite. Figures are estimated on the basis of reported tonnage dollar value.

[4]Year beginning March 21 of that stated.

[5]Reported figure.

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MANGANESE

By Lisa A. Corathers

Domestic survey data and tables were prepared by Elena M. Lita, statistical assistant, and the world production tables were prepared by Glenn J. Wallace, international data coordinator.

In 2005, U.S. manganese apparent consumption was an estimated 766,000 metric tons (t), a 24% decrease from 1.01 million metric tons (Mt) in 2004 (table 1). Decreases in manganese ore shipments from the Government's National Defense Stockpile, and ferromanganese, silicomanganese, and manganese metal imports accounted for most of the decline in apparent consumption.

Manganese imports decreased by 9% on a content basis compared with those of 2004 (table 6). Manganese exports decreased by 66% compared with those of 2004 on a content basis, based on the typical manganese contents of the materials noted in table 5.

In 2005, the price of ore rose from that of 2004, while the average prices of manganese ferroalloys declined (except manganese metal). The price of metallurgical-grade ore increased by 63% internationally. Prices for high- and medium-carbon ferromanganese and silicomanganese declined from the historic high in 2004 by 52%, 31%, and 42%, respectively.

In 2005, sales of manganese materials from the Government's National Defense Stockpile (NDS) reduced the Government's inventory of manganese by 10% (content basis), leaving an inventory of 94% of the annual apparent consumption. The larger disposals (reported sales) were of metallurgical-grade ore and high-carbon ferromanganese.

World production of manganese ore in 2005 rose by 5% on a gross-weight basis and by 9% on a contained-weight basis, compared with that in 2004 (table 7). China was the leading producer on a gross-weight basis; South Africa was the leading producer on a contained-weight basis. Combined world production of ferromanganese and silicomanganese rose by 8% on a gross-weight basis compared with that in 2004 (table 8). China was the leading producer of these manganese ferroalloys.

Manganese is essential to iron and steel production by virtue of its sulfur-fixing, deoxidizing, and alloying properties. Steelmaking, including its ironmaking component, accounted for most of the domestic manganese demand, currently in the range of 85% to 90% of the total consumption. Among a variety of other uses, manganese is a key component of certain widely used aluminum alloys, and is used in oxide form in dry cell batteries.

Legislation and Government Programs

Air Quality, Emission Limits.—The U.S. Environmental Protection Agency (EPA) issued amended national emission standards for hazardous air pollutants (HAPs) for industrial, commercial, and institutional boilers and process heaters. One of the metallic HAPs at each of these sources is manganese. The EPA used a health-based alternative standard for manganese emissions (U.S. Environmental Protection Agency, 2005, p. 76921, 76933-76935).

Air Quality, Public Health Study.—In July, the Agency for Toxic Substances and Disease Registry (ATSDR) of the U.S. Department of Health and Human Services reported the results of the residential-rain-water-cistern sampling investigation conducted by the Ohio Department of Health (ODH) on June 29, 2004. The ODH sampled 9 cisterns for 15 metals, including manganese, as part of the ATSDR investigation on potential health impacts from air emissions around the former Union Carbide facility complex near Marietta, OH. The complex is currently occupied by Chevron-Phillips Chemical Company, Eramet Marietta, Inc., Eveready Battery, and Solvay Advanced Polymers, LLC. The ODH found that the levels of metals detected in the cistern water would not be expected to cause adverse health effects to the residents (Agency for Toxic Substances and Disease Registry, 2005§[1]).

Stockpile.—The revised Annual Materials Plan (AMP) for fiscal year 2005 that the Defense National Stockpile Center (DNSC) of the Defense Logistics Agency issued on February 1, 2005, covered the period from October 1, 2004, through September 30, 2005. Under this AMP, the maximum disposal authority for manganese materials was 453,592 t for metallurgical-grade ore; 90,718 t for the high-carbon ferromanganese; 36,287 t for chemical-grade ore; 27,216 t for natural battery-grade ore; 2,732 t for synthetic manganese dioxide; and 1,814 t for electrolytic manganese metal (Defense National Stockpile Center, 2005). The maximum disposal authority under an AMP is the maximum quantity of material that may be disposed in a given fiscal year as authorized by Congress; these may differ from the disposal authority quantities listed in table 2.

For 2005, disposals (reported sales) of manganese materials announced by the DNSC totaled 248,981 t for stockpile-grade metallurgical-grade ore; 69,967 t for high-carbon ferromanganese; 34,542 t for chemical-grade ore; 2,964 t for synthetic manganese dioxide; and 1,083 t for natural battery-grade ore.

The NDS physical inventory of manganese materials, in gross weight, indicated that all inventories decreased except stockpile-grade metallurgical ore (increased by 106,694 t). The decreases consisted of 308,187 t for nonstockpile-grade metallurgical ore; 49,250 t for high-carbon ferromanganese; 11,503 t for chemical-grade ore; 5,532 t for natural battery-grade ore; and 2,466 t for electrolytic manganese metal (Defense National Stockpile Center, unpub. data, December 2005). In 2005, the estimated manganese content of manganese inventories being held by the Government at yearend was lowered by 10% to 721,000 t. On the basis of manganese content, the total remaining inventory was 94% of the current national apparent consumption.

[1]References that include a section mark (§) are found in the Internet References Cited section.

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Production

Ore and Concentrate.—The only mine production of manganese in the United States consisted of small amounts of manganiferous material having a natural manganese content of less than 5%. This type of material was produced in South Carolina for use in coloring brick.

Chemicals, Ferroalloys, and Metal.—Production statistics for these materials were concealed to avoid disclosing company proprietary data. Domestic producers of manganese ferroalloys, metal, and synthetic dioxide are listed in table 3.

Globe Metallurgical Inc., a U.S. silicon company, produced silicomanganese for the first time during January through March. In March, Prince Mineral Company, Inc. acquired American Minerals, Inc., a manganese chemical producer, from Imerys SA of France (Palladium Equity Partners LLC, 2005§).

Highlanders Alloy LLC sporadically produced silicomanganese during the year; the company reportedly shut down a furnace in April after restarting it in October 2004, resumed production in August 2005 and then was shut down again in October and November (Ryan's Notes, 2005b, g). On May 27, Highlanders and its holding company, Global Industrial Projects LLC, filed Chapter 11 bankruptcy (Ryan's Notes, 2005c). On January 6, 2006, the U.S. bankruptcy court agreed to the $20 million sale of Highlanders to Felman Production, a Delaware corporation owned by Ukrainian Privat Group (Ryan's Notes, 2006a). The new owners planned to produce high-carbon ferromanganese and silicomanganese (Ryan's Notes, 2006b).

In October, Kerr-McGee Corp. (a division of Anadarka Petroleum Corporation) spun off its chemical business, which included electrolytic manganese dioxide, through an initial public offering (IPO) of its wholly owned subsidiary Tronox Incorporated (formerly Kerr-McGee Chemical LLC) (Anadarka Petroleum Corporation, 2005§). The IPO closed on November 28 (Tronox Incorporated, 2005§).

Consumption, Uses, and Stocks

Data relating to manganese end use and certain other information have indicated that metallurgical applications account for most domestic manganese consumption, 85% to 90% of which has been for steelmaking. In 2005, reported U.S. ore consumption indicated that unit consumption of manganese in ironmaking, which could not be published to avoid disclosing company proprietary data, declined from that of 2004 to remain a relatively minor component of overall manganese use in steelmaking. Reported consumption (gross weight) of silicomanganese, manganese metal, and ferromanganese decreased from that in 2004, by 16%, 12%, and 9%, respectively (table 4). Because of the incompleteness of reporting to the U.S. Geological Survey (USGS) voluntary consumption survey, the figures in this table are more representative of relative rather than absolute quantities.

Data on domestic consumption of manganese ore, exclusive of that consumed within the steel industry, are collected by means of the "Manganese Ore and Products" survey. In 2005, 12 firms were canvassed that process ore or had processed ore in the past by such methods as grinding and roasting or that consume ore in the manufacture of dry cell batteries and manganese ferroalloys, metal, and chemicals. Of those 12 companies, 9 consumed manganese ore in their processes. The collective consumption of these firms is thought to constitute all the manganese ore consumption in the United States, exclusive of that by the steel industry. Full-year responses or a basis upon which to estimate the data were obtained from all of these firms for 2005, excluding Highlanders.

The combination of the indicated consumption pattern with estimates of apparent consumption, on a gross-weight basis, suggests that manganese unit consumption in steelmaking was 5.4 kilograms per ton (kg/t) or 1.9 times that calculated on the basis of reported consumption in 2005. This level was 29% less than the revised quantity of 7.6 kg/t estimated for 2004 and was a result of significant decreases in apparent consumption of ferromanganese and silicomanganese. Decreases in apparent consumption were attributable to significant decreases in imports of these materials.

Relatively small quantities of manganese were used for alloying with nonferrous metals, chiefly in the aluminum industry as manganese-aluminum briquettes that typically contained either 75% or 85% manganese. Manganese plays an important alloying role in aluminum to increase corrosion resistance. The most important use of aluminum-manganese alloys is in the manufacture of soft drink cans. Other uses include automobiles, cookware, radiators, and roofing (Harben and others, 1998, p. 80-105).

Comparatively small amounts of manganese were used domestically in animal feed, brick coloring, dry cell batteries, fertilizers, and manganese chemicals. These were among the many nonmetallurgical applications of manganese (Weiss, 1977, p. 221-323; Harben and others, 1998, p. 80-105). The source of manganese units for these applications was mainly manganese ore.

In 2005, domestic consumption of manganese ore decreased by 17% to 368,000 t, while corresponding yearend stocks increased by 112% to 337,000 t (table 1). To avoid disclosing company proprietary data, these figures exclude the relatively small quantities associated with ironmaking and cannot be disaggregated into end-use segments.

Prices

Manganese Ore.—The USGS estimated the average annual contract price of metallurgical-grade ore containing 48% manganese to be $4.39 per metric ton unit (mtu). Prices were above or below this value, depending on ore quality, time of year, and nature of transaction. The year-average spot market price for this grade of ore based on weekly averages of North American transaction prices as reported by Ryan's Notes was $3.21 per mtu. The range in spot market prices hit a high in March at $4.20 to $4.50 per mtu, and a low in early December at $2.30 to $2.40 per mtu. The price of a metric ton of ore is obtained by multiplying the mtu price by the percentage manganese content of the ore; for example, by 48 when the manganese content is 48%. The ore market consisted of a number of submarkets because of differences between ores according to such end uses as ferroalloy production, blast furnace ironmaking, and manufacture of manganese chemicals.

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The price of manganese in ore in 2005 and 2004 was 43.9 and 28.9 cents per kilogram, respectively. These values indicate an increase of 52% in U.S. cost, insurance, freight (c.i.f.) price, or 17% less than the increase in free on board (f.o.b.) price in international markets compared with those in 2004.

In fiscal year 2005 (April 2005 to March 2006), the international benchmark price for metallurgical-grade ore increased by 63% from that in 2004, when price negotiations between BHP Billiton Ltd. and major Japanese consumers were concluded in February. On an f.o.b. basis for delivery during the annual contract year, the agreed price was $3.99 per mtu for ore from the Groote Eylandt Mine in Australia (Ryan's Notes, 2005d). The rise in manganese ore prices was attributable primarily to increased demand for manganese ferroalloys by the steel industry coupled with tight ore supplies and rising transportation costs.

Manganese Ferroalloys and Metal.—Prices for manganese ferroalloys tend to vary in response to changes in demand by the steel and ferrous foundry industries, while those of manganese metal predominantly follow changes in demand by the aluminum industry. Manganese ferroalloy prices are also influenced by changes in the product mix of the world's suppliers because they are largely interchangeable.

Year-average import prices for manganese ferroalloys are given by Platts Metals Week. These prices are based on free market spot prices per unit of measurement, f.o.b. Pittsburgh, PA, or Chicago, IL, warehouse. Year-average import prices were $638.83 per gross ton for high-carbon ferromanganese, 59.37 cents per pound for medium-carbon ferromanganese, and 34.84 cents per pound for silicomanganese. These prices were 52%, 31%, and 42% lower, respectively, than those of 2004. The year-average price for manganese metal is based on weekly averages of North American transaction prices published by Ryan's Notes for bulk shipments of manganese metal, f.o.b. Chicago, IL or Pittsburgh, PA, warehouse. The year-average North American transaction price for manganese metal was 89.20 cents per pound, which was a 2% increase compared with that of 2004. The year-average price for manganese metal was 22% less than the last listed U.S. price for domestically produced electrolytic manganese metal of $1.15 per pound at the beginning of 1996.

Prices for both grades of ferromanganese and silicomanganese declined based on decreased demand from the domestic steel sector and greater supply during 2005. Manganese metal prices rose in response to increased demand from the domestic aluminum sector.

According to Platts Metals Week, the price range for high-carbon ferromanganese containing 78% manganese, per gross ton, began the year unchanged from the end of 2004 at $880 to $950 and ended the year at $710 to $750, for a net decrease of 20%. The price range for medium-carbon ferromanganese with a manganese content of 80% to 85% and a nominal carbon content of 1.5%, per pound of manganese, began the year at 78 to 82 cents (about the same as that of yearend 2004) and ended the year at 48 to 51 cents, for a net decrease of 38%. The price range for imported silicomanganese with 2% carbon, per pound of alloy, started the year unchanged from that at the end of 2004 at 40 to 43 cents and ended 2005 at 36 to 39 cents, for a net decrease of 10%.

According to the North American transaction prices listed by Ryan's Notes, the 2005 yearend price of bulk manganese metal shipments was 70 to 74 cents per pound, a net decrease of 26% from the 2004 yearend price of 95 to 100 cents per pound.

Foreign Trade

In the absence of domestic mine production and recycling, U.S. net import reliance, as a percentage of apparent consumption, was 100% for manganese, the same as it has been for the past 20 years. The ensuing comparisons of foreign trade data were made on the basis of gross weight.

U.S. exports of ferromanganese, manganese dioxide, and silicomanganese increased during 2005, while exports of manganese metal and ore decreased (table 5). The biggest year-to-year change in exports was that of manganese ore, which decreased 89% compared with those in 2004. China accounted for 47% of manganese ore exports, followed by France at 24%.

U.S. imports of manganese dioxide and manganese ore increased during 2005 compared with those of 2004, while imports of ferromanganese, manganese metal, potassium permanganate, and silicomanganese fell (table 6). The most significant year-to-year change was for imports of manganese ore; these were 45% more than those of 2004. Increases in this import subcategory were especially notable for those from Gabon, with an increase of 123,000 t (34%), and from South Africa, with an increase of 41,000 t (153%) year-on-year.

Imports of spiegeleisen (pig iron containing 20% manganese) decreased to 291 t in 2005 from 389 t in 2004, on a gross-weight basis, with a total customs value of $291,454 or $1,000 per metric ton. Most of these imports were from South Africa (99%), with the remaining from India (U.S. Census Bureau, unpub. data, December 2005).

Pending U.S.-Southern African Customs Union Free Trade Agreement.—Representatives from the Office of the United States Trade Representative (USTR) and member nations of the Southern African Customs Union (Botswana, Lesotho, Namibia, South Africa, and Swaziland) continued negotiations on the pending U.S.-Southern African Customs Union Free Trade Agreement (FTA). In April 2006, the parties agreed to establish a framework for pursuing the FTA over the longer term (Office of the United States Trade Representative, 2006§). The USTR launched negotiations for the FTA on June 2, 2003 (Office of the United States Trade Representative, 2003§). The FTA could result in the permanent elimination of the 14% ad valorem duty on all imports of unwrought manganese—manganese flake [Harmonized Tariff Schedule of the United States (HTS) subheading 8111.00.47] and "other" unwrought manganese articles, such as manganese powder and manganese-aluminum briquettes (HTS subheading 8111.00.49)—from South Africa.

Silicomanganese Imports from Brazil (December 1, 2002, through November 30, 2003).—On April 13, the International Trade Administration (ITA) of the U.S. Department of Commerce made a final determination that two of Companhia Vale do Rio Doce's (CVRD) wholly owned subsidiaries—Rio Doce Manganês S.A. (RDM) and Urucum Mineracao S.A. (Urucum)—did not sell the subject imports at prices below

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normal value, and as a result no duty would be imposed (International Trade Administration, 2005a).

Silicomanganese Imports from Brazil (December 1, 2003, through November 30, 2004).—On September 9, the ITA preliminarily determined that RDM and Urucum did not sell the subject imports at prices below normal value, and as a result no duty would be imposed (International Trade Administration, 2005b).

Potassium Permanganate Imports from China.—On May 18, the U.S. International Trade Commission (ITC) announced the results of its 5-year (sunset) review of the antidumping duty order on potassium permanganate from China. The ITC found that revocation of the existing antidumping duty order would likely lead to a continuation or recurrence of material injury within the foreseeable time to the domestic industry. Therefore, the existing order would remain in place (U.S. International Trade Commission, 2005§).

World Industry Structure

The bulk (97%) of manganese ore was produced in 10 countries. On a content basis, the leading producer countries of manganese ore were, in decreasing order, South Africa, Brazil, Australia, Gabon, China, and Ukraine (table 7). On a gross weight basis, the leading producer countries of manganese ferroalloys were, in decreasing order, China, Ukraine, South Africa, Brazil, Japan, Norway, Australia, and Russia (table 8).

Francaviglia (2006§) estimated that world apparent consumption of manganese ferroalloys declined by 2% to 10.7 Mt in 2005 compared with that of 2004. Of that amount, 6.1 Mt was silicomanganese, 3.6 Mt was high-carbon ferromanganese, and 1.0 Mt was refined (medium- and low-carbon) ferromanganese. Manganese ore apparent consumption was 10.75 Mt (content basis), about the same as that of 2004.

World Review

Australia.—The Australian Government reported manganese ore resources increased by 7.6% in 2004 to 133 Mt, primarily because of the addition of Bootu Creek resources in the Northern Territory and an increase in resources at the Woodie Woodie Mine. (These resources are described in the Manganese chapter of the 2004 Minerals Yearbook, volume I, Metals and Minerals). Manganese ore reserves that met the Australasian Joint Ore Resources Committee (JORC) code were 95 Mt in 2004, all of which were located in the Groote Eylandt deposit owned by Groote Eylandt Mining Company Pty. Ltd. (GEMCO) in the Northern Territory (Geoscience Australia, 2005§).

Bootu Creek Resources Pty. Ltd. (a subsidiary of Singapore's OM Holdings) continued development of a 600,000-metric-ton-per-year (t/yr) manganese mine in the Northern Territory. Mine operations were expected to start in March or April 2006 (Intierra Resource Intelligence, 2005§). In December, the company assumed complete ownership of the project by acquiring GEMCO's remaining 25% interest (OM Holdings Limited, 2005§).

In December, Churchill Mining PLC purchased Black Peak Holdings Pty. Ltd.'s 20% stake in the mining tenement that includes the Enacheddong Creek prospect within Churchill's South Woodie Woodie Manganese project area. As a result, Churchill now wholly owns the tenement (Churchill Mining PLC, 2005§). The South Woodie Woodie Manganese Project is located 40 kilometers south of Consolidated Minerals Ltd.'s Woodie Woodie Mine. The highest priority target within the project area is the Enacheddong Creek prospect; rock samples collected during 2005 returned assays up to 51.5% manganese, with 57 of 74 samples containing greater than 30% manganese. The company continued to explore other deposits in the region (Churchill Mining PLC, 2006§).

Consolidated Minerals Ltd. (2006§) reported a 46% increase in manganese ore production to 888,432 t at its Woodie Woodie Mine during fiscal year 2006 (July 1, 2005, to June 30, 2006). Production capacity also increased to 1.1 million metric tons per year (Mt/yr) of 48% manganese ore from 800,000 Mt/yr. As a result of recent exploration activities, the company augmented its total manganese resources by 823,900 t to 15.5 Mt, after allowance for depletion by mining. Of that amount, JORC reserves were estimated to be 9.5 Mt with an average grade of 42.7% manganese. The increased resources equate to a 15-year mine life.

Bahrain.—Bahrain Ferroalloys B.S.C. (c) planned to start a new ferroalloys plant in May by first producing manganese ferroalloys. Initial production capacity was set at 60,000 t/yr, increasing to 90,000 t/yr in 2006 (Metal-Pages, 2005a§). The plant, located in the Hidd Industrial Area, is the first nonintegrated ferroalloy producer in the country. The plant can produce a mix of alloys, which includes ferrochromium, ferrosilicon, high- and medium-carbon ferromanganese, and silicomanganese (Bahrain Ferro Alloys B.S.C. (c), 2006§).

Brazil.—Mining Journal (2005a) reported that the production capacity of CVRD's Azul Mine, located in Carajas, State of Para, would expand to 2.5 Mt/yr by yearend 2005. In September, Carvalho (2005§) reported that CVRD would invest R$140 million ($59.4 million) through 2008 to modernize its Rio Doce Manganês ferroalloy processing plant located in Simoes Filho, State of Bahia. Of that amount, R$45 million ($19.5 million) would first be spent on installing a 165,000-t/yr sinter plant to agglomerate fine manganese ores for more efficient use in mill furnaces. As a result of these investments, productivity was expected to increase to 210,000 t/yr from 170,000 t/yr in 2005.

China.—To reduce ferroalloy and metal exports, China's Ministry of Finance revoked the 8% export tax rebate on ferromanganese and silicomanganese starting January 1, 2005, and the 13% export tax rebate on manganese metal effective August 1 (TEX Report, 2005e, Metal-Pages, 2004§). Effective August 22, China's Ministry of Commerce abolished its so-called preferential "Red Book" system for toll refining agreements whereby the 13% value-added tax on manganese ore imports and 5% export tax on manganese ferroalloy exports had been waived (TEX Report, 2005b). A toll refining agreement, or tolling, describes the situation in which the owner of ore or concentrate contracts the refining of the metal to another party for a fee, but the refined metal remains under the original ownership for final sale or disposition (U.S. Bureau of Mines, 1996).

The Central Government of China, through the National Development and Reform Commission (NDRC), estimated the

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number of ferroalloy producers in the country to be 1,570; total installed production capacity was 22 Mt/yr (twice that of 2000). Some 1.16 Mt of ferroalloy capacity was under construction, with an additional 1.23 Mt planned. Ferroalloy production during the year was 10.67 Mt, and the amounts consumed, exported, and imported were 9.30 Mt, 1.74 Mt, and 370,000 t, respectively. China accounted for 40% of global ferroalloy production and 30% each of global consumption and exports (TEX Report, 2006c, d).

Because of overcapacity, the NDRC issued a bulletin on July 5 that established a national system for approving state-owned ferroalloy companies. The new system would also reduce energy consumption and increase environmental protection by the ferroalloys industry. The NDRC also set the following limits for energy consumed in the production of manganese ferroalloys: 5,800 kilowatthours per metric ton (kWh/t) of medium-carbon ferromanganese; 4,200 kWh/t of silicomanganese; and 2,600 kWh/t of high-carbon ferromanganese (TEX Report, 2005c, d).

As part of the approval process, state-owned ferroalloy producers were required to report the following information: total capital, profit, number of production facilities, the amount of energy consumed, and environmental protection controls at plant operations. Plant inspections would be conducted to verify compliance with regulations instituted in 2004 as described in the Silicon chapter of the 2004 Minerals Yearbook, volume I, Metals and Minerals. The NDRC announced the names of 33 manganese ferroalloy producers that met environmental standards as of December 31 (TEX Report, 2006c, d).

The Central Government of China also ordered electrolytic manganese metal producers in the Huaheng area of Hunan Province to cease operations in late September because of noncompliance with environmental regulations. The Government allowed one company, Dongfang Mengye, to restart production shortly thereafter. Dongfang's electrolytic manganese metal production capacity was reported to be 30,000 t/yr (TEX Report, 2005f). In 2005, China produced 569,000 t of electrolytic manganese metal, and had the capacity to produce 1.118 Mt/yr. Production was primarily centered in the following areas: Chongqing City, Guangxi Zhuang Autonomous Region, Guizhou Province, and Hunan Province. The number of Chinese electrolytic manganese metal producers was estimated to be 156 (TEX Report, 2006a).

China Metal Market (2005) reported that construction began in early spring on the Xianming Manganese Mine in Daxin County of Guangxi Zhuang Autonomous Region. The mine, with an initial investment of Y5 million (US$604,000), was to start in June. No production capacity or average grade of the 300,000-t proven manganese reserves was reported. According to the TEX Report (2006a), 600 mines produced 10.75 Mt of manganese ore in 2005; of that amount, 55% was manganese dioxide and 45% was manganese carbonate. Chinese manganese ore production capacity was estimated to be 12 Mt/yr.

Jinzhou Nichiden Ferroalloy Ferroalloy Co., Ltd. delayed the startup of its new 50,000-t/yr silicomanganese plant in the Liaoning Province until April 2006 from August 2005. Construction of the facility began in July 2005 (TEX Report, 2005h).

Eramet SA began construction of a new electrolytic manganese dioxide plant for alkaline batteries in Chongzuo, Guangxi Province. Total production capacity is planned to be 20,000 t/yr, starting with 10,000 t/yr in early 2007 (Eramet SA, 2006a§).

France.—In March, a major transformer failure caused a decline in production at Eramet's Dunkerque silicomanganese facility; a loss of at least 15,000 t was expected. The company made up for some of the lost output from its Norwegian facilities (Ryan's Notes, 2005a). From August to December, Rio Doce Manganèse Europe (CVRD) operated its ferroalloy plant in Dunkerque at 50% of capacity (5,670 metric tons per month) (Companhia Vale Do Rio Doce, 2006a§, b§).

Gabon.—Compagnie Minière Trois Rivières (CMTR) (a subsidiary of CVRD) continued exploring manganese deposits in the Franceville and Okondjá regions in Haute Ogooué Province. As part of its feasibility studies, CMTR began operating a pilot plant with a feed capacity of 5 metric tons per hour in Franceville at the end of 2005. Should the project prove feasible, CVRD announced it would invest US$33 million in infrastructure and logistics projects needed to commence mining; these would start in January 2007 and conclude in 2009 (Companhia Vale do Rio Doce, 2006c§).

According to Eramet SA's online manganese profile, production capacity at its Moanda Mine in Gabon would increase to 3.5 Mt/yr from 3 Mt/yr in 2008 (Eramet SA, 2006c§). The Moanda Mine is operated by the company's subsidiary Compagnie Miniere de l'Ogooue (Comilog). The company planned to spend €30 million (US$37.8 million) on the mine expansions (Ryan's Notes, 2005f). Gross production at the mine reportedly was 2.859 Mt in 2005 (Eramet SA, 2006b§).

Georgia.—The Chiatura district court initiated bankruptcy proceedings against Georgian manganese ore producer Chiaturmarganets. This action will allow the future sale of the company's net assets (Interfax Metals & Mining Weekly, 2005).

Ghana.—Ghana Manganese Company Limited increased production at its Nsuta Mine by 5.8% to 1.6 Mt in 2005 (Mining Journal, 2005b).

Kazakhstan.—The parent company of Alloy 2000, owner of the Zhairem GOK manganese mine complex (Zhairem) located in the Karaganda Region, reorganized as Eurasian Natural Resources Corporation (ENRC) in October. ENRC is based in Zurich, Switzerland. As a result, Alloy 2000 changed its name to ENR Ferroalloys AG (TEX Report, 2005a).

Sittard (2005§), chairman and chief executive officer of ENRC, reported the following information: (1) manganese ore reserves of 10.8 Mt (22.8% manganese content) at the Tur Mine, 3.9 Mt (19% manganese content) at the Vostochny Kamys Mine, and 91 Mt (28% manganese content) at Zhairem; (2) total manganese concentrate capacity in 2004 was 700,000 t/yr; (3) construction of a new 400,000-t/yr ore preparation (dressing) plant at Vostochny Kamys Mine by 2006; and (4) capital investments in Zhairem were planned at US$16 million in 2004, US$30 million in 2005, US$17.5 million in 2006, US$11 million in 2007; US$7.5 million in 2008, and US$2 million in 2009. The planned expansions at Zhairem would increase production capacity to 1.8 Mt/yr by yearend 2006 and to 2.5 Mt/yr by 2008 (TEX Report, 2005g).

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Mexico.—Minera Autlán planned to start its new US$5 million sinter plant at the company's Tamós ferroalloy plant during the third quarter of 2005. The plant would have an annual production capacity of 300,000 t/yr (Metal Pages, 2005b§).

Norway.—From August to December, Rio Doce Manganese Norway (owned by CVRD) curtailed ferroalloy production at its Mo I Rana plant. Production capacity of the plant is 110,000 t/yr (Companhia Vale do Rio Doce, 2006a§, b§).

Russia.—In 2005, Chelyabinsk Electrometallurgical Kombinat (Chelyabinsk) expected to produce 275,000 t of high-carbon ferromanganese, and 125,000 t of low-carbon ferromanganese (TEX Report, 2005i).

Sittard (2005§) reported that silicomanganese production in Russia during 2004 was 113,000 t, and ferromanganese production was 87,500 t. The major silicomanganese producer in 2004 was Chelyabinsk at 97%. OAO Kosgorsky Metallurgical Plant and Satkinsky Iron Works accounted for 52% and 48% of the ferromanganese domestic market in 2004, respectively.

South Africa.—The South African Government awarded new manganese leases (or farms) to seven companies pursuant to the mining charter requirements mandated by the South African Mineral and Petroleum Resources Development Act of 2002; these became effective May 1, 2004. The mining charter, which was established, in part, to encourage black economic empowerment (BEE), calls for a 26% ownership of South African mining industry assets by historically disadvantaged South Africans (HDSAs) in 10 years, with a 15% HDSA-ownership level in 5 years (South Africa Department of Minerals and Energy Affairs, 2002§). As noted in the charter, HDSAs include blacks, people living in mining communities, and women.

Ownership of the new manganese leases are as follows: Asia Minerals Ltd (Hong Kong) and Dirleton Minerals & Energy (Pty.) Ltd. (South Africa) will divide the Devon, Hotazel, Kipling, Perth, Telele, and York farms; Metmar Trading (Pty.) Ltd. (Kalahari Rescources (Pty.) Ltd., South Africa), the Gama, Olive Pan, and Umtu farms; Renova Group (Russia) and its BEE partners, Chancellor House and Pitsa Ya Setshaba Holdings, the Botha, Middelplatts, Mooidraai, Rissik, Roldraai, and Smartt farms; and Xstrata Plc (Switzerland) and its BEE partner, Ditswammung Mineral Resources Consortium, the Belgravia, Bergheim, Epsom, Olivewood, Santoy, and Tigerplan farms (Ryan's Notes, 2005h).

By the end of September, Highveld Steel and Vanadium Corporation Limited (2005b§) brought five of its seven manganese ferroalloy furnaces back online at its Transalloys plant. The company had shut all the furnaces down in June because of low export prices, high electricity, and raw material costs (Highveld Steel and Vanadium Corporation Limited, 2005a§). The plant comprises two medium-carbon ferromanganese and five silicomanganese furnaces (Ryan's Notes, 2005i).

Ukraine.—Sittard (2005§) reported that silicomanganese and ferromanganese production in Ukraine was 900,000 t and 430,000 t, respectively. The major silicomanganese producers in 2004 were Nikopol Ferroalloy Plant (NFZ) (68%) and OAO Zaporozhsky Ferro-Alloy Works (32%). NFZ, Kramatorsky Metallurgical Plant, and Zaporozhsky accounted for 65%, 18%, and 17% of the ferromanganese domestic market, respectively.

The dispute between NFZ and the Ukrainian manganese ore producers continued in 2005. Since 2003, NFZ sporadically purchased manganese concentrates from Ordzhonikidziyevsky GOK, the country's largest manganese ore producer, because it thought they were overpriced (Interfax Metals & Mining Weekly, 2004). NFZ turned to imports to meet all its raw material needs in October 2004, shortly after the Ukrainian government ruled against applying special measures on manganese ore imports (Metal-Pages, 2005c§).

In addition to its impasse with Ukrainian manganese ore producers, NFZ was beset by uncertainties in ownership during 2005. In late August, the Dnipropetrovsk Regional Economic Court (DREC) ruled that Ukrainian Interpipe Group's purchase of 50% plus one share in NFZ from the State Property Fund of Ukraine (SPFU) in 2003 was illegal, and ordered the Government to reprivatize NFZ (Ryan's Notes, 2005e, p. 2). The Supreme Court upheld the DREC decision in January 2006 (State Property Fund of Ukraine, 2006a§). In February 2006, Ryan's Notes (2006c) reported that the Ukrainian Government had asked the country's privatization board to prepare NFZ for reprivatization, although it had not yet received the disputed Interpipe shares being held by Ukrsocbank. The Ministry of Justice confirmed on February 23, 2006, that the SPFU could not become owner of those shares until Ukrsocbank transferred them (State Property Fund of Ukraine, 2006b§). In addition to the court cases, the Parliament passed a law to prevent the NFZ sale on February 9, 2006; the law was vetoed by President Victor Yushcenko on February 20, 2006 (President of Ukraine, 2006§).

Current Research and Technology

Among many items in the current literature that reported on various aspects of manganese and the topics addressed were the following:

Battery Technology.—A123Systems, Watertown, MA, introduced new lithium-ion rechargeable batteries whose cathodes are made out of nanoscale-phosphate materials doped with metal ions, such as manganese (Amato, 2006, p. 82). The company reported that the new batteries have up to five times the power density and 10 times the life of current rechargeable, high-power batteries. Targeted applications include advanced medical devices, consumer electronics, hybrid vehicles, and mobility products, such as electric scooters, power tools, and robotics (A123Systems, 2005§).

Environment and Toxicology.—Researchers at the Medical Research Council's Institute for Environment (University of Leicester, England) and the Institute of Occupational Medicine recommended a respirable manganese limit of 0.1 milligrams per cubic meters (mg/m^3), and a supplementary respirable limit of 0.5 mg/m^3 in cases where gastrointestinal exposure is significant after inhalation, for workers exposed to inorganic forms of manganese. A short-term occupational exposure limit is not required (Institute for Environment and Health/Institute of Occupational Medicine, 2004§).

Wyckoff and McBride (2004) reported on the health effects and increasing number of worker lawsuits in the United States resulting from occupational exposure to manganese from welding.

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Manganese Ocean Nodules.—The United Nations' International Seabed Authority (ISA) (2005§) deferred consideration and adoption of new regulations governing the exploration of deep seabeds for deposits such as polymetallic sulfide nodules and cobalt-rich iron-manganese crusts. As these sites are typically in international waters, the ISA has been trying to develop complex regulations dealing with legal, business, and environmental issues regarding their mining and dredging (Mining Journal, 2005c).

Pyrometallurgy.—Kumba Resources Limited successfully demonstrated its new AlloyStream™ technology to produce ferromanganese directly from fine manganese ore at its Pretoria, South Africa, pilot plant. The use of such ores was previously limited by existing smelting technologies (Kumba Resources Limited, 2006§). The AlloyStream technology reportedly lowers the cost of ferromanganese production by 30% to 50% by using cheaper reductant and less electric power than conventional technology (Metals Place, 2006§).

Outlook

The trend of domestic and global demand for manganese is expected to follow closely that of steel production, for which the combined annual growth rates have been typically in the range of 1% to 2% in the United States. Although growth rates for some nonmetallurgical components of manganese demand, especially batteries, may be higher than for steel production, this situation will have only a minor effect on overall manganese demand.

Details of the outlook for the steel industry are discussed in the Outlook section of the Iron and Steel chapter of the 2005 USGS Minerals Yearbook, volume I, Metals and Minerals. Raw steel production decreased by 5% in the United States while increasing 6% globally from that in 2004. According to the International Iron and Steel Institute, world apparent consumption of finished steel products increased by 4.1% to 1,013 Mt in 2005 from that in 2004 (International Iron and Steel Institute, 2006§). This increase was primarily attributed to steel consumption in Asia, particularly in China. Asia accounted for 55% of steel consumed worldwide in 2005, up 10.1% to 554.9 Mt from that in 2004. China alone consumed 315 Mt, a 16.7% increase from that of the prior year. Steel consumption in 2005 was also up in Africa, the Commonwealth of Independent States, and the Middle East.

As evidenced in 2005, manganese apparent consumption does not always track steel production precisely because of the influence of unmeasured changes in stocks of manganese materials, such as those of importers and consumers. The effect of this may outweigh changes in demand by steelmakers and may explain why for some years calculated apparent consumption showed positive or negative deviations from that which could be estimated on the basis of steel production.

Demand for manganese metal comes primarily from the aluminum industry followed by the steel industry. The outlook for the aluminum industry is discussed in the Outlook section of the Aluminum chapter of the 2005 USGS Minerals Yearbook, volume I, Metals and Minerals.

Demand for EMD comes from the primary and secondary battery industries. As a rough indicator of EMD demand, U.S. demand for primary and secondary batteries is projected to increase 5.9% annually through 2009 to $14.8 billion. Of that amount, secondary battery demand was 65%. Secondary battery sales were forecast to rise faster than those of primary batteries, at an annual rate of 6.5% compared with 5.0% for primary batteries, owing in part to strong growth in the use of high-drain portable electronic products (Freedonia Group, Inc., The, 2005§).

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TABLE 1
SALIENT MANGANESE STATISTICS[1]

(Thousand metric tons, gross weight, unless otherwise specified)

	2001	2002	2003	2004	2005
United States:					
Manganese ore (35% or more Mn):					
Exports	9	15	18	123	13
Imports for consumption	358	427	347	451	656
Consumption[2]	425	360	398	441	368
Stocks, December 31, consumers[2]	138	151	156	159	337
Ferromanganese:					
Exports	9	9	11	9	14
Imports for consumption	251	275	238	429	255
Consumption	266	253	248	315	286
Stocks, December 31, consumers and producers	25	21	20	25 r	30
Consumption, apparent, manganese content[3]	692	696	643	1,010 r	766
Ore price, c.i.f.[4] U.S. ports, dollars per metric ton unit	2.44	2.30	2.41	2.89	4.39
World, production of manganese ore	20,900	22,200 r	24,100 r	27,700 r	29,100 e

eEstimated. rRevised.
[1]Data are rounded to no more than three significant digits.
[2]Exclusive of iron and steel plants.
[3]Based on estimates of average content for all significant components except imports, for which content is reported.
[4]Cost, insurance, and freight.

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TABLE 2
U.S. GOVERNMENT DISPOSAL AUTHORITIES AND INVENTORIES FOR MANGANESE MATERIALS AS OF YEAREND 2005[1]

(Metric tons, gross weight)

Material	Disposal authority	Physical inventory[e] Uncommitted Stockpile grade	Uncommitted Nonstockpile grade	Uncommitted Total	Sold, pending shipment	Grand total
Synthetic manganese dioxide	--	--	--	--	266	266
Natural battery ore	--	--	--	--	18,400	18,400
Chemical ore	--	--	--	--	27,000	27,000
Metallurgical ore	144,000	--	144,000	144,000	265,000	409,000
High-carbon ferromanganese	612,000	612,000	--	612,000	14,900	627,000
Electrolytic metal	--	--	--	--	--	--

[e]Estimated. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: Defense National Stockpile Center.

TABLE 3
DOMESTIC PRODUCERS OF MANGANESE PRODUCTS IN 2005

Company	Plant location	Products[1] FeMn	SiMn	MnO_2	Type of process
Energizer Holdings, Inc., Eveready Battery Co.	Marietta, OH			X	Electrolytic.
Erachem Comilog	Baltimore, MD			X	Chemical.
Do.	New Johnsonville, TN			X	Electrolytic.
Eramet Marietta Inc.	Marietta, OH	X	X		Electric furnace.
Globe Metallurgical, Inc.[2]	Beverly, OH		X		Do.
Highlanders Alloys LLC[3]	New Haven, WV		X		Do.
Tronox LLC	Henderson, NV			X	Electrolytic.

[1]FeMn, ferromanganese; SiMn, silicomanganese; MnO_2, synthetic manganese dioxide.

[2]Globe produced SiMn from January through March 2005.

[3]Product information obtained from various industry trade publications.

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TABLE 4

U.S. CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF MANGANESE FERROALLOYS AND METAL IN 2005[1]

(Metric tons, gross weight)

End use	Ferromanganese			Silicomanganese	Manganese metal
	High carbon	Medium and low carbon	Total		
Steel:					
Carbon	128,000	82,700	211,000	52,400	793
High-strength, low-alloy	16,600	7,100	23,700	3,440	11
Stainless and heat-resisting	7,700	1,140	8,850	13,600	1,220
Full alloy	17,300	5,300	22,600	19,400	25
Unspecified[2]	1,210	72	1,290	736	1,690
Total	171,000	96,300	267,000	89,600	3,740
Cast irons	6,750	505	7,260	440	5
Superalloys	W	W	W	--	W
Alloys (excluding alloy steels and superalloys)	522	330	852	2,980	14,600
Miscellaneous and unspecified		W	W	(3)	W
Total consumption	183,000	103,000	286,000	93,000 [4]	18,300
Total manganese content[5]	143,000	82,300	225,000	61,400	18,300
Stocks, December 31, consumers and producers	10,800	19,600	30,300	8,330	2,500

W Withheld to avoid disclosing company proprietary data; included with "Alloys (excluding alloy steels and superalloys)." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes electrical and tool steel.

[3]Withheld to avoid disclosing company proprietary data.

[4]Internal evaluation indicates that silicomanganese consumption is considerably understated.

[5]Estimated based on typical percent manganese content.

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TABLE 5

U.S. EXPORTS OF MANGANESE ORE, FERROALLOYS, AND METAL, BY COUNTRY[1]

Country	2004		2005	
	Quantity, gross weight (metric tons)	Value, f.a.s.[2] (thousands)	Quantity, gross weight (metric tons)	Value, f.a.s.[2] (thousands)
Ore and concentrates with 20% or more manganese:				
Brazil	1,090	$137	--	--
Canada	5,130	1,450	3,000	$893
China	89,000	5,360	6,390	1,820
France	242	119	3,300	99
Germany	10,900	2,320	172	407
Italy	74	36	--	--
Netherlands	6,240	808	--	--
Norway	1,790	430	--	--
Sweden	1,660	334	94	244
United Kingdom	4,010	410	--	--
Other	2,870	1,010	511	480
Total	123,000	12,400	13,500	3,940
Ferromanganese, all grades:				
Canada	6,230	6,400	10,400	12,000
Mexico	458	660	4,070	2,850
Venezuela	390	764	--	--
Other	2,040	2,810	30	39
Total	9,118	10,634	14,500	14,889
Silicomanganese:				
Canada	46	53	300	351
Mexico	277	314	359	409
Other	179	265	240	457
Total	502	632	899	1,220
Metal, including alloys and waste and scrap:				
Belgium	318	733	1,100	1,590
Canada	824	1,980	273	805
Japan	730	1,290	564	1,170
Mexico	273	605	197	435
Sweden	186	125	124	87
Other	458	1,360	420	1,880
Total	2,790	6,090	2,670	5,960
Manganese dioxide:				
Belgium	256	302	292	368
Canada	1,960	890	3,400	1,630
Israel	210	345	67	85
Mexico	400	327	635	641
United Kingdom	170	205	19	19
Other	1,000	1,610	1,490	2,290
Total	4,000	3,680	5,900	5,030

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship.

Source: U.S. Census Bureau.

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TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY[1]

Country	2004			2005		
	Quantity		Value, customs (thousands)	Quantity		Value, customs (thousands)
	Gross weight (metric tons)	Mn content (metric tons)		Gross weight (metric tons)	Mn content (metric tons)	
Ore and concentrates with 20% or more manganese:						
All grades:						
Australia	52,400	27,700	$5,550	41,100	21,300	$5,700
Gabon	363,000	188,000	28,200	485,000	252,000	39,100
Mexico	4,400	1,640	385	8,810	4,320	1,030
South Africa	26,900	13,200	2,070	68,000	33,100	7,170
Other	4,940	2,840	1,570	52,900	23,200	5,170
Total	451,000	234,000	37,700	656,000	334,000	58,200
More than 20% but less than 47% manganese:						
Gabon	1,540	706	439	4,060 [2]	4,950 [2]	1,180
Mexico	4,400	1,640	385	8,810	4,320	1,030
Other	18	8	8	31,300	11,500	3.21
Total	5,950	2,360	832	44,100	20,800	4,200
47% or more manganese:						
Australia	52,400	27,700	5,550	41,100	21,300	5,700
Gabon	361,000	188,000	27,700	481,000 [3]	247,000 [3]	37,900
South Africa	26,900	13,200	2,070	68,000	33,100	7,170
Other	4,920	2,830	1,560	21,700	11,700	3,180
Total	445,220	231,730	36,880	612,000	313,000	53,990
Ferromanganese:						
All grades:						
Australia	31,500	22,900	24,900	4,960	3,810	2,630
Brazil	12,900	9,150	7,910	19,900	15,700 [3]	12,200
China	71,000	53,000	61,300	26,900	22,000	34,500
France	4,010	3,170	3,850	4,100	3,200	2,830
India	11,800	9,000	13,300	--	--	--
Japan	1,200	965	1,230	3,300	2,650	3,830
Korea, Republic of	13,300	10,700	13,700	15,700	12,400	14,300
Mexico	15,800	12,500	14,900	22,400	17,800	23,500
Norway	26,600	20,700	27,900	2,170	1,680	3,090
South Africa	188,000	146,000	193,000	149,000	117,000	99,300
Other	52,300	46,300	52,100	6,330	5,420	3,380
Total	428,000	334,000	414,000	255,000	202,000	200,000
1% or less carbon:						
China	8,850	7,830	12,700	14,700	12,600	24,100
Japan	1,200	965	1,230	3,300	2,650	3,830
Mexico	2,650	2,120	2,780	7,940	6,360	8,610
Norway	2,960	2,410	4,940	240	197	385
South Africa	1,890	1,750	2,860	3,250	2,730	5,340
Other	57	46	67	2,710	2,090	3,070
Total	17,600	15,100	24,600	32,200	26,600	45,300
More than 1% to 2% or less carbon:						
China	17,300	13,800	20,200	3,150	2,520	4,490
Korea, Republic of	10,100	8,330	10,400	13,000	10,400	11,400
Mexico	13,100	10,300	12,000	13,700	10,800	14,200
Norway	6,940	5,670	8,280	1,810	1,480	2,610
South Africa	43,100	35,000	46,800	28,700	23,300	30,800
Other	6,160	4,840	6,610	14	9	25
Total	96,700	78,000	104,000	60,300	48,500	63,400

See footnotes at end of table.

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TABLE 6—Continued

U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY[1]

Country	2004 Quantity Gross weight (metric tons)	2004 Quantity Mn content (metric tons)	2004 Value, customs (thousands)	2005 Quantity Gross weight (metric tons)	2005 Quantity Mn content (metric tons)	2005 Value, customs (thousands)
Ferromanganese—Continued:						
More than 2% but not more than 4% carbon:						
China	476	393	$649	--	--	--
Georgia	5,990	5,640	5,530	--	--	--
South Africa	--	--	--	61	48	$31
Total	6,470	6,030	6,180	61	48	31
More than 4% carbon:						
Australia	31,500	22,900	24,900	4,960	3,810	2,630
Brazil	12,900	9,150	7,910	19,900	15,700 [3]	12,200
China	44,300	31,000	27,800	9,040	6,890	5,940
France	4,010	3,170	3,850	4,100	3,200	2,830
India	11,800	9,000	13,300	--	--	--
Norway	16,700	12,700	14,700	114	92	100
South Africa	143,000	109,000	143,000	117,000	90,900	63,100
Other	43,400	38,200	43,200	7,060	5,460	4,010
Total	308,000	235,000	279,000	162,000	126,000	90,900
Silicomanganese:						
Australia	29,500	19,600	24,600	35,400	23,500	20,900
Georgia	34,300	26,300	33,200	14,500	10,900	8,890
Korea, Republic of	16,800	10,900	13,100	5,220	3,410	3,280
Mexico	12,300	8,070	8,160	27,300	18,100	18,600
Norway	77,500	41,000	59,900	53,400	33,700	52,000
Romania	70,300	50,300	75,200	71,100	48,100	51,500
Russia	28,900	11,400	15,500	14,500	9,960	11,400
South Africa	143,000	94,200	148,000	101,000	66,600	61,100
Spain	1,400	933	1,910	4,000	2,670	2,770
Other	8,100	5,830	6,760	1,210	916	711
Total	422,000	269,000	386,000	327,000	218,000	231,000
Metal:						
Unwrought[4]:						
China	14,200	XX	21,100	16,000	XX	24,100
Germany	796	XX	1,580	2,550	XX	4,900
South Africa	15,000	XX	21,800	11,000	XX	20,500
Other	1,480	XX	2,540	2,800	XX	6,600
Total	31,500	XX	47,000	32,300	XX	56,200
Other manganese, wrought:						
China	349	XX	552	320	XX	522
Spain	208	XX	459	94	XX	204
Other	119	XX	643	37	XX	453
Total	676	XX	1,650	451	XX	1,180
Waste and scrap:						
Canada	2,470	XX	1,150	639	XX	178
China	17	XX	26	--	XX	--
France	20	XX	53	--	XX	--
Mexico	--	XX	--	--	XX	--
Other	21	XX	28	(5)	XX	5
Total	2,530	XX	1,250	639	XX	183

See footnotes at end of table.

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TABLE 6—Continued

U.S. IMPORTS FOR CONSUMPTION OF MANGANESE ORE, FERROALLOYS, METAL, AND SELECTED CHEMICALS, BY COUNTRY[1]

Country	2004			2005		
	Quantity		Value, customs (thousands)	Quantity		Value, customs (thousands)
	Gross weight (metric tons)	Mn content (metric tons)		Gross weight (metric tons)	Mn content (metric tons)	
Manganese dioxide:						
Australia	7,970	XX	$9,780	15,900	XX	$21,000
China	11,300	XX	11,400	10,300	XX	10,900
Greece	2,340	XX	2,960	--	XX	--
Ireland	--	XX	--	--	XX	--
South Africa	1,020	XX	1,460	--	XX	--
Other	3,780	XX	5,220	5,290	XX	7,550
Total	26,400	XX	30,800	31,500	XX	39,500
Potassium permanganate:						
Czech Republic	767	XX	1,480	666	XX	1,410
India	342	XX	674	317	XX	634
Other	7	XX	64	65	XX	140
Total	1,120	XX	2,220	1,050	XX	2,190

XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]All or part of these data have been referred to the U.S. Census Bureau for verification.

[3]Part of these data were revised by the U.S. Census Bureau.

[4]Imports of unwrought metal include flake, powder, and other.

[5]Less than ½ unit.

Source: U.S. Census Bureau, adjusted by the U.S. Geological Survey.

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TABLE 7
MANGANESE ORE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	Mn content, percentage[e, 4]	2001	2002	2003	2004	2005
Australia:[5]						
Gross weight		2,069	2,187	2,555	3,381	4,000
Mn content	37-53	948	983	1,247	1,327	1,450
Brazil:[6]						
Gross weight		1,970	2,529	2,544	3,143 r	3,150
Mn content	37-51	988	1,095	1,286	1,346 r	1,592
China:[e, 7, 8]						
Gross weight		4,300	4,500	4,600	5,500 r	5,500
Mn content	20-30	860	900	920	1,100 r	1,100
Gabon:[9]						
Gross weight		1,791	1,856	2,000	2,460 r	2,500
Mn content[e]	45-53	830	810	873	1,090	1,290
Ghana:						
Gross weight		1,077	1,136	1,509	1,624	1,915
Mn content[e]	32-34	344	363	480	525	613
India:[e, 10]						
Gross weight		1,600	1,700	1,650	1,700	1,750
Mn content	10-54	600	630	620	630	640
Kazakhstan, crude ore:						
Gross weight		1,387	1,792	2,361	2,318 r	2,208
Mn content[e]	20-30	350	440	580	570 r	540
Mexico:[11]						
Gross weight		277	245 r	320 r	377 r	470
Mn content	36-37r	100	88	115 r	136	180
South Africa:[9]						
Gross weight		3,266	3,322	3,501	4,207	4,612
Mn content	30-48+	1,479	1,504	1,585	1,905	2,100
Ukraine:						
Gross weight		2,700	2,470	2,591	2,362	2,260
Mn content[e]	30-35	930	840	880	810	770
Other:[e, 12]						
Gross weight		490	478 r	484 r	651 r	762
Mn content	XX	142 r	143 r	137 r	191 r	239
Total:						
Gross weight		20,900	22,200	24,100	27,700 r	29,100
Mn content	XX	7,570 r	7,800	8,720 r	9,630 r	10,500

[e]Estimated. [p]Preliminary. [r]Revised. XX Not applicable.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 21, 2006. Data pertain to concentrates or comparable shipping product, except that in a few instances, the best data available appear to be for crude ore, possibly after some upgrading.

[3]In addition to the countries listed, Cuba, Panama, and Sudan may have produced manganese ore and/or manganiferous ore, but available information is inadequate to make reliable estimates of output levels.

[4]May be average content of each year's production rather than for content of typical products.

[5]Metallurgical ore.

[6]Production of beneficiated ore as reported in the Mineral Summary for each year listed, as published by the National Department of Mineral Production, Brasilia, Brazil.

[7]Includes manganiferous ore.

[8]The International Manganese Institute estimated Chinese manganese ore production, in gross weight and Mn content, respectively, to be as follows: 2004—8,500,000 metric tons (t) and 1,700,000 t; and 2005—12,000,000 t and 2,400,000 t.

[9]Calculated metal content includes allowance for assumed moisture content. Includes ore and sinter.

[10]Much of India's production grades below 35% Mn; content averaged 38.3% Mn for fiscal years 2001-02 through 2005-06.

[11]Mostly oxide nodules; may include smaller quantities of direct-shipping carbonate and oxide ores for metallurgical and battery operations.

[12]Category represents the combined totals of Bosnia and Herzegovina, Bulgaria, Burkina Faso, Burma, Chile, Colombia, Egypt, Georgia,

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TABLE 8

FERROMANGANESE AND SILICOMANGANESE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, gross weight)

Country[3]	2001	2002	2003	2004[e]	2005[e]
Argentina, electric furnace, silicomanganese[e]	5,150 [4]	5,000	5,000	5,000	5,000
Australia, electric furnace:[e]					
Ferromanganese	115,000	115,000	115,000	115,000	120,000
Silicomanganese	135,000	135,000	135,000	135,000	140,000
Total	250,000	250,000	250,000	250,000	260,000
Brazil, electric furnace:					
Ferromanganese	276,000 [r]	339,000 [r]	438,000 [r]	508,000 [r]	510,000 [p]
Silicomanganese	180,235	182,731	180,200	180,000	108,200 [p]
Total	456,235 [r]	521,731 [r]	618,200 [r]	688,000 [r]	618,200 [p]
Chile, electric furnace, ferromanganese	2,213	--	--	--	--
China:[e]					
Blast furnace, ferromanganese	500,000	500,000	550,000	590,000 [r]	600,000
Electric furnace:					
Ferromanganese	670,000	490,000	700,000	1,120,000 [r]	1,100,000
Silicomanganese	1,170,000	1,580,000	1,800,000	2,600,000	3,800,000
Total	2,340,000	2,570,000	3,050,000	4,310,000 [r]	5,500,000
Egypt, electric furnace, ferromanganese[e]	30,000	30,000	30,000	30,000	30,000
France:[e]					
Blast furnace, ferromanganese	300,000	300,000	180,000	--	--
Electric furnace:					
Ferromanganese	130,000	130,000	120,000	106,000	110,000
Silicomanganese[5]	50,000	50,000	107,000	64,000	65,000
Total	480,000	480,000	407,000	170,000	175,000
Georgia, electric furnace:[e]					
Ferromanganese	100 [4]	-- [4]	--	--	--
Silicomanganese	25,000	25,000	25,000	25,000	25,000
Total	25,100	25,000	25,000	25,000	25,000
India, electric furnace:[e]					
Ferromanganese	165,000	165,000	165,000	170,000	170,000
Silicomanganese	150,000	150,000	160,000	160,000	170,000
Total	315,000	315,000	325,000	330,000	340,000
Indonesia, electric furnace:[e]					
Ferromanganese	12,000	12,000	12,000	12,000	12,000
Silicomanganese	7,000	7,000	7,000	7,000	4,000
Total	19,000	19,000	19,000	19,000	16,000
Italy, electric furnace:[e]					
Ferromanganese	40,000	40,000	40,000	40,000	40,000
Silicomanganese	90,000	90,000	90,000	90,000	90,000
Total	130,000	130,000	130,000	130,000	130,000
Japan, electric furnace:					
Ferromanganese	368,293	356,717	371,831	437,389 [r, 4]	448,616 [4]
Silicomanganese	62,238	70,965	58,043	73,041 [r, 4]	94,725 [4]
Total	430,531	427,682	429,874	510,430 [r, 4]	543,341 [4]
Kazakhstan, electric furnace:					
Ferromanganese	5,349	2,278	1,931	2,000	2,100
Silicomanganese	141,200	164,000	178,920	155,324 [r, 4]	170,214 [4]
Total	146,549	166,278	180,851	157,324 [r, 4]	172,314 [4]
Korea, North, electric furnace, ferromanganese[e]	6,000	6,000	6,000	6,000	6,000
Korea, Republic of, electric furnace:					
Ferromanganese	143,525	137,000 [e]	141,000	165,525 [r, 4]	165,000
Silicomanganese	101,877	94,000 [e]	90,942 [r]	82,917 [r, 4]	83,000
Total	245,402	231,000 [e]	231,942 [r]	248,442 [r, 4]	248,000

See footnotes at end of table.

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TABLE 8—Continued

FERROMANGANESE AND SILICOMANGANESE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, gross weight)

Country[3]	2001	2002	2003	2004[e]	2005[e]
Mexico, electric furnace:[6]					
Ferromanganese	60,014	38,532	55,903	72,471 [4]	89,641 [4]
Silicomanganese	74,290	73,263	81,223	103,206 [4]	104,780 [4]
Total	134,304	111,795	137,126	175,677 [4]	194,421 [4]
Norway, electric furnace:[e]					
Ferromanganese	240,000	240,000	245,000	245,000	250,000
Silicomanganese	230,000	230,000	230,000	230,000	230,000
Total	470,000	470,000	475,000	475,000	480,000
Poland:[e]					
Blast furnace, ferromanganese	500	600	1,000 [r]	1,000 [r]	1,000
Electric furnace, silicomanganese	20,000 [4]	7,500	-- [r]	-- [r]	--
Total	20,500 [4]	8,100	1,000 [r]	1,000 [r]	1,000
Romania, electric furnace:					
Ferromanganese	384	--	--	--	--
Silicomanganese	71,921	84,720 [r]	141,899 [r]	194,945 [r, 4]	200,000
Total	72,305	84,720 [r]	141,899 [r]	194,945 [r, 4]	200,000
Russia:[e]					
Blast furnace, ferromanganese	55,000	105,000	101,000	108,000	108,000
Electric furnace, silicomanganese	124,000	127,000	83,000	143,000	145,000
Total	179,000	232,000	184,000	251,000	253,000
Slovakia, electric furnace:[e]					
Ferromanganese	20,000	20,000	20,000	20,000	20,000
Silicomanganese	35,000	35,000	35,000	35,000	35,000
Total	55,000	55,000	55,000	55,000	55,000
South Africa, electric furnace:					
Ferromanganese	524,000 [r]	618,954	607,362	612,000 [r, 4]	510,000
Silicomanganese	253,000	315,802	313,152	340,000	280,000
Total	777,000 [r]	934,756	920,514	952,000 [r]	790,000
Spain, electric furnace:[e]					
Ferromanganese	10,000	10,000	10,000	10,000	10,000
Silicomanganese	100,000	100,000	100,000	100,000	100,000
Total	110,000	110,000	110,000	110,000	110,000
Ukraine:					
Blast furnace, ferromanganese[e]	85,000	85,000	85,000	79,000 [r]	30,000
Electric furnace:					
Ferromanganese	231,000	250,617	250,000 [e]	375,990 [4]	330,000
Silicomanganese	702,389	732,592	740,000 [e]	1,060,000 [4]	1,000,000
Total	1,018,389	1,068,209	1,080,000 [e]	1,510,000 [r]	1,360,000
United States, electric furnace, ferromanganese[7]	W	W	W	W	W
Venezuela, electric furnace:					
Ferromanganese[e]	12,715 [4]	12,000	12,000	15,000	15,000
Silicomanganese	56,640	36,974	30,632	35,000	35,000
Total	69,355	48,974	42,632	50,000	50,000
Grand total	7,790,000 [r]	8,300,000 [r]	8,850,000 [r]	10,700,000 [r]	11,600,000
Of which:					
Blast furnace, ferromanganese	941,000	991,000	917,000	778,000 [r]	739,000
Electric furnace, excluding United States:					
Ferromanganese[8]	3,060,000 [r]	3,010,000 [r]	3,340,000 [r]	4,060,000 [r]	3,940,000
Silicomanganese[9]	3,780,000	4,300,000	4,590,000 [r]	5,820,000 [r]	6,880,000

See footnotes at end of table.

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TABLE 8—Continued

FERROMANGANESE AND SILICOMANGANESE: WORLD PRODUCTION, BY COUNTRY[1, 2]

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Grand total." -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through August 2, 2006.

[3]In addition to the countries listed, Iran is believed to have produced ferromanganese and silicomanganese, but production information is inadequate for the formulation of estimates of output levels.

[4]Reported figure.

[5]Includes silicospiegeleisen, if any.

[6]Salable products from Cía Minera Autlán S.A. de C.V.

[7]U.S. output of ferromanganese includes silicomanganese.

[8]Ferromanganese includes silicomanganese, if any, for North Korea.

[9]Includes silicospiegeleisen, if any, for France.

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MERCURY

By William E. Brooks

Domestic tables were prepared by Subina W. Pandey, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

There were no mercury mines in production in the United States in 2005. The McDermitt Mine in Nevada, the last mine to produce mercury as its principal product, closed in 1992. Mercury was produced in 2005 in the United States as a byproduct of domestic gold and silver processing, mainly in Nevada, and may have been produced as a byproduct of processing other metals. Mercury was also produced from reclaiming and recycling fluorescent lamps and a declining supply of mercury-containing dental amalgam, medical devices, and thermostats. The chlorine-caustic soda industry, the leading domestic user of mercury, recycled some of its mercury in-plant. Data on domestic byproduct and recycled mercury production were not available.

In 2005, mercury imports totaled 212 metric tons (t), and exports totaled 319 t. Peru (128 t) and Chile (31 t) were the leading sources of imported mercury, and the Netherlands (156 t), Mexico (25 t), Spain (21 t), Guyana (19 t), and India (19 t) were the principal destinations for mercury exported in 2005.

Since 1927, the common unit for measuring and pricing mercury has been the "flask," which was set to conform to the system used at Almaden, Spain (Meyers, 1951). One flask weighs 34.5 kilograms, and 1 t of mercury contains approximately 29 flasks.

Legislation and Government Programs

In June, the U.S. Environmental Protection Agency (EPA) sponsored a workshop entitled "Global Partnership for Mercury Management in Artisanal and Small-Scale Gold Mining." Papers were presented on health issues in mining areas that use mercury and nonmercury alternatives for small-scale gold mining. For example, in Guyana, the use of mercury for gold recovery was common; however, because of a proposed ban on mercury use in the gold mining sector, several mercury-free methods, such as gravity concentration, sluice boxes, centrifuges, and shaking tables, were recommended (Viera, 2005, p. 5).

Under current U.S. law, powerplants that emit 10 metric tons per year (t/yr) of a single toxin, such as mercury or arsenic, or 25 t/yr or more of a combination of toxins must install technology that would cut those emissions by 95%. A draft rule proposed by the EPA would lift that requirement from plants that keep their emissions under the 25 t/yr limit. Critics, however, argued that if the draft rule were to be put in place, plants could run their controls at one-half speed and continue to emit toxic elements (Eilperin, 2006).

Mercury has been used as a component of dental amalgam for more than a century, but because of mercury's toxicity, its continued use is controversial. U.S. Government-funded studies on children in New England and Portugal found no evidence that mercury-containing dental fillings cause brain damage or other neurological problems in children (DeRouen and others, 2006§[1]).

At yearend 2005, the Defense Logistics Agency's (DLA) National Defense Stockpile (NDS) held an inventory of 4,436 t of mercury at several sites in the United States. Mercury sales from the NDS stockpile were suspended in 1994 in response to environmental concerns. In early 2004, the DLA indicated that the mercury would be consolidated at one site in Nevada (Joseph Johnson, specialist, Defense Logistics Agency, written commun., April 30, 2004).

Production

Mercury has not been mined as a principal product in the United States since closure of the McDermitt Mine in Nevada in 1992. In 2005, byproduct mercury and calomel (HgCl) were produced at several gold and silver mines in Nevada. Byproduct mercury from gold mines in Chile and Peru was imported, further refined, and sold for domestic use or export. HgCl was captured by pollution-control devices at ore roasters at domestic and foreign smelters to recover mercury for resale (Bethlehem Apparatus Co., 2005§). Data on the amount of byproduct mercury and calomel produced in the United States are not available.

Consumption

For the period 1996 through 2004, an average of slightly more than 100 t of mercury was purchased annually by the chlorine-caustic soda industry (Arthur E. Dungan, Vice President, The Chlorine Institute, written commun., May 13, 2005). Annual purchases of replacement mercury indicate that some mercury-containing industrial waste, described as "amalgam" may have been landfilled in the United States or Canada or lost to the environment. The overall market shift toward nonmercury alternatives for chlorine-caustic soda production and other mercury applications continued owing to global human health and environmental concerns about anthropogenic mercury releases.

Only about 200 t of mercury is consumed domestically each year. Despite human health concerns, mercury usage is not carefully tracked, and the U.S. Geological Survey does not canvass for its consumption (Brooks and Matos, 2005§). Therefore, domestic mercury consumption for 2005 was broadly estimated to be 50% for chlorine-caustic soda manufacture and 50% for dental applications, electronics, fluorescent lamps, and switches. Owing to concern for the environment, fluorescent lamps that contain from 40% to 54% less mercury, depending

[1]References that include a section mark (§) are found in the Internet References Cited section.

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on style of lamp, are now being manufactured (Koninklijke Philips Electronics N.V., 2005§). The chlorine-caustic soda industry purchased an average of slightly more than 100 t/yr of replacement mercury for its mercury cell plants from 1996 to 2005.

Prices

According to Platts Metals Week (2005), mercury prices ranged from a low of $600 per flask in January-February to a high of $950 per flask in March and settled at $700 to $850 per flask in the third and fourth quarters of 2005. Mercury prices were $350 to $555 per flask in 2004. This overall rise in price, especially when compared with 2000-03 when the average price was $140 per flask, correlates with a diminished supply of mercury from recycled mercury-containing products and apparent growth in the global demand for mercury for small-scale gold mining. High gold prices encouraged increased use of mercury for gold recovery by small-scale gold miners worldwide.

Recycling

In 2005, mercury was reclaimed and recycled from automobile convenience switches, dental amalgam, fluorescent lamps, lab/medical devices, and thermostats. No data are available on the amount of mercury recycled. The mercury was reclaimed from these devices by treatment in multistep high-temperature retorts in which the mercury is first volatized and then condensed for purification and sale (Brooks and Matos, 2005§). The major companies that recycled mercury in 2005 included AERC.com, Inc., Allentown, PA; Bethlehem Apparatus Company, Bethlehem, PA; Clean Harbors Environmental Services, Inc., Braintree, MA; D.F. Goldsmith Chemical and Metal Corporation, Evanston, IL; Mercury Waste Solutions, Mankato, MN; and Onyx Environmental Services, Lombard, IL. As many as 50 companies were listed as mercury recyclers in 2002 (Mercury Recyclers, 2002§); however, their role was mainly collection of mercury-containing materials that would be moved on to larger facilities for retorting.

Some mercury used for chlorine-caustic soda manufacture was recycled and reused in-plant. However, unknown amounts of mercury-containing industrial waste from the chlorine-caustic soda plants may have been landfilled in the United States or in Canada instead of being recycled. Chlorine-caustic soda sludge was specifically included on a list of waste types accepted at a dedicated placement site in Canada (Stablex Canada Inc., 2005§). In 2005, a total of 1,160 t of amalgam (not chemically defined) was exported, mainly to Canada (970 t), the United Kingdom (28 t), and Mexico (21 t).

Diaphragm and membrane cells are nonmercury alternatives for chlorine and caustic soda production (Roskill Information Services Ltd., 1990, p. 65). The ultimate closure of the United States' nine remaining mercury-cell chlorine-caustic soda plants could make approximately 3,000 t of mercury available for recycling (Raloff, 2003§).

Copper, lead, and zinc processing produce residue and waste that may contain mercury and other byproducts. Collaboration between Oak Ridge National Laboratory and the Colorado School of Mines resulted in a process that separates mercury from sulfuric acid plant sludge at copper smelters. The process involves use of a commercially available rotary vacuum kiln that can produce mercury for recycling as well as a process stream that can also be sold to recover trace amounts of lead, gold, and silver (Berry and others, 2000§).

Foreign Trade

The total amount of mercury imported in 2005 was 212 t, which was more than double the 92 t of mercury imported in 2004. Peru (128 t) and Chile (31 t) were the principal sources. Imports of mercury from Peru increased to 128 t in 2005 from 0 t in 2004 possibly owing to stockpiling of byproduct mercury at gold smelters in Peru before shipment.

World Review

In 2005, world mercury mine production was estimated to be 1,680 t, which was somewhat more than the average amount produced from 2000 to 2004. Production estimates have a high degree of uncertainty, however, because most companies and countries do not report primary (including byproduct) or secondary production data owing to environmental and health concerns. In 2005, China (1,100 t), Spain (250 t), and Kyrgyzstan (200 t) were the apparent leaders in world mine production of mercury. In China, mercury has historically been produced as a byproduct of gold mining and from mercury mines in the Upper Yangtze, Kuniun-Qinling, Sanjiang, and South China metallogenic regions (Lixian and Ruolan, 1992, p. 147).

Mercury use for artisanal or small-scale gold mining is a significant but untracked use of the metal in Ghana, Indonesia, Peru, Venezuela, Vietnam, and elsewhere. The mercury is used to amalgamate gold flakes and may be released to the environment during mining and gold recovery from the amalgam. In 1997, it was estimated that more than 200 t/yr of mercury was released through artisanal or small-scale mining in Latin America (Viega, 1997§). Recent estimates indicated that, in Indonesia alone, up to 60 t/yr of mercury may be lost at individual gold mining concessions, or units, in gold mining areas (Alfred Whitehouse, Director, International Programs, U.S. Department of the Interior, Office of Surface Mining, oral commun., May 16, 2006).

World Industry Structure

Europe.—In April, the European Environmental Bureau (EEB) sponsored an international conference entitled "Towards a Mercury-Free World" in Madrid, Spain, to address global mercury issues. Topics included global mercury production, use, and trade; symptoms of chronic mercury intoxication; mercury in breast milk as a health hazard for infants in gold mining areas; gold mining in the Amazon; and Swedish policy for a mercury-free environment. Attendees included consultants and representatives from Brazilian, Chinese, and European environmental organizations and major mercury producers and consumers (Elena Lymberidi, Zero Mercury Project coordinator,

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European Environmental Bureau, written commun., November 15, 2005).

In Europe, there were 80 chlorine-caustic soda plants, and 48 of these were mercury-cell plants. The date for closure of the mercury-cell plants is voluntary but is expected to be no later than 2020. It was estimated that there was 11,500 t of mercury in the cells of the remaining plants (Barrie S. Gilliatt, executive director, Euro Chlor, written commun., November 25, 2005).

Latin America.—Peru was an important producer of byproduct mercury and a significant consumer of mercury. At Barrick's Pierina gold mine in northern Peru, mercury was retorted from Merrill-Crowe precipitates and then shipped to the United States for processing or refining (Michael Merry, logistics superintendent, Minera Barrick Misquichilca, oral commun., May 3, 2005). Byproduct mercury recovered from Minera Yanacocha, S.R.L.'s Yanacocha gold mine was also shipped to the United States. Before use, Minera Yanacocha's mercury flasks are drop-tested for security and measured for standard dimensions. After the flasks are filled, the mercury is chemically tagged, and the flask caps are double-sealed. Then the filled flasks are placed into a larger container that is bolted shut before shipment to the United States for recycling. In collaboration with the U.S. Department of Energy's Brookhaven National Laboratory, Minera Yanacocha was researching ways to chemically stabilize and encapsulate elemental mercury onsite (Ron Bradburn, process manager, Minera Yanacocha, S.R.L., written commun., June 1, 2005).

As part of an ongoing international environmental program between Peru and Switzerland, three retorts have been built near Arequipa, Peru. These retorts will help miners recover their gold without being exposed to mercury fumes, prevent losses of mercury to the environment, and provide better recovery of gold (Miguel Yepez, Economic Section, U.S. Embassy, Lima, Peru, written commun., April 4, 2006). The Arequipa region is an important small-scale gold mining area in Peru where both mercury and cyanide are routinely used to recover gold and has been the focus of a study by the Peruvian geological agency Instituto Geologico Minero y Metalurgico (Canepa, 2005).

In Brazil and Venezuela, mercury treatment centers have been established where artisanal miners can take their gold-mercury concentrates for retorting and recovery of the gold and mercury. These centers are important and reduce health risks to miners, who would commonly burn their amalgam in the open air to drive off the mercury, and limit mercury releases to the environment.

Current Research and Technology

The United States' 11,000 coal-fired powerplants may emit as much as 48 t/yr of mercury (U.S. Environmental Protection Agency, 2005§). Officials in nine northeastern States came to a preliminary agreement to reduce mercury emissions by 10 % by 2020 (DePalma, 2005§). To meet these objectives, chemical engineers were researching pollution control technology that uses bromine, chlorine, or gold to scrub the mercury from powerplant emissions (Larry S. Monroe, pollution program manager, Southern Company Generation and Energy Marketing, oral commun., June 1, 2006).

Outlook

Global mercury use is expected to continue to decline. Mercury-containing thermometers, perhaps the most visible use of mercury, have been replaced by digital thermometers or thermometers using "galistan," an alloy of gallium, indium, and tin (Pennsylvania Department of Environmental Protection, 2004§). Ceramic material is now widely used in place of controversial, mercury-containing dental amalgam. The closure of mercury cell chlorine-caustic soda production facilities in Europe, India, South America, and the United States, which have come under pressure from international environmental and health organizations, will result in reduced demand for replacement mercury and release of large amounts of mercury for disposal, recycling, or storage. The use of mercury for artisanal gold mining in many parts of the world will likely continue. In the near term, high gold prices are expected to increase demand for use in artisanal mining and stimulate increased gold exploration and production. In turn, this will encourage byproduct mercury production as large mines open.

Releases to the environment may ultimately be lessened by the reduction of mercury emissions by coal-fired powerplants and copper, gold, and zinc mines and smelters; stricter laws and enforcement of bans on mercury use in artisanal gold mining; and monitoring of mercury releases and industrial waste by the chlorine-caustic soda industry. Recycled mercury from mercury cell chlorine-caustic soda plants, byproduct mercury recovered from domestic and foreign gold operations, and mercury contained in the DNS will be more than adequate to meet domestic needs.

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TABLE 1
SALIENT MERCURY STATISTICS[1]

(Metric tons unless otherwise specified)

	2001	2002	2003	2004	2005
United States:					
Secondary production, industrial	NA	NA	NA	NA	NA
Imports for consumption	100	209	46	92	212
Exports	108	201	287	278	319
Industry stocks, yearend[2]	NA	NA	NA	NA	NA
Industrial consumption	NA	NA	NA	NA	NA
Price, average, free market[3] dollars per flask	140	140	140	365	555
World, mine production	1,500	1,490	1,370 r	1,890 r	1,680 e

eEstimated. rRevised. NA Not available.

[1]Data are rounded to no more than three significant digits, except prices.

[2]Stocks at consumers and dealers not available. Mine stocks withheld to avoid disclosing company proprietary data.

[3]Source: Platts Metals Week.

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TABLE 2

U.S. IMPORTS AND EXPORTS OF MERCURY, BY COUNTRY[1]

Country	2004 Quantity, gross weight (metric tons)	2004 Value (thousands)	2005 Quantity, gross weight (metric tons)	2005 Value (thousands)
Imports:				
Canada	2	$15	13	$62
Chile	60	119	31	210
China	--	--	(2)	4
Germany	24	1,170	11	620
Israel	5	46	29	343
Peru	--	--	128	1,280
United Kingdom	(2)	3	(2)	12
Other	(2)	4 r	--	--
Total	92	1,350	212	2,530
Exports:				
Australia	--	--	5	144
Canada	4	28	11	87
Chile	3	11	4	30
Colombia	--	--	6	129
Guyana	--	--	19	465
Hong Kong	--	--	17	340
India	63	347	19	385
Korea, Republic of	(2)	8	1	27
Mexico	64	860	25	453
Netherlands	--	--	156	2,850
Peru	47	98	--	--
Philippines	--	--	4	129
Saudi Arabia	2	25	3	78
Spain	--	--	21	375
United Arab Emirates	--	--	14	111
Vietnam	79	546	3	62
Other	16 r	383 r	10	146
Total	278	2,310	319	5,810

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 3

U.S. IMPORTS AND EXPORTS OF AMALGAMS[1] OF PRECIOUS METALS, WHETHER OR NOT CHEMICALLY DEFINED, BY COUNTRY[2]

	2004		2005	
Country	Quantity, gross weight (metric tons)	Value (thousands)	Quantity, gross weight (metric tons)	Value (thousands)
Imports:				
Brazil	--	--	(3)	$334
Canada	30	$18,900	6	15,600
Colombia	--	--	(3)	22
Germany	19	15,700	4	8,050
Ireland	3	16,200	(3)	2,500
Italy	(3)	175	1	1,320
Japan	1	2,230	(3)	501
Malaysia	--	--	28	3,670
Mexico	3	370	2	526
Netherlands	18	2,680	4	675
Russia	4	29,200	4	49,600
South Africa	(3)	369 r	(3)	499
Spain	1	88	--	--
Switzerland	(3)	3	(3)	611
Taiwan	--	--	(3)	1,390
United Kingdom	(3)	14,200	2	3,810
Other	1	334	(3)	13
Total	79	100,000	51	89,100
Exports:				
Australia	6	6,770	6	7,300
Brazil	6	8,270	--	--
Canada	49	28,400	970	73,500
China	101	4,300	18	8,990
France	(3)	648	2	554
Germany	3	1,420	4	1,610
India	26	4,840	3	13,200
Ireland	1	637	(3)	861
Italy	--	--	(3)	548
Japan	2	2,170	4	1,160
Korea, Republic of	--	--	2	573
Mexico	194	79,500	21	98,600
Netherlands	16	6,810	12	8,210
Singapore	4	3,750	10	5,510
Switzerland	1	1,110	--	--
Taiwan	8	1,570	8	3,420
United Kingdom	3	3,160	28	6,460
Other	183	1,730	77	649
Total	603	155,000	1,160	231,000

rRevised. -- Zero.

[1]An alloy of mercury with one or more other metals.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 4
U.S. IMPORTS OF MERCURY CHLORIDE[1] BY COUNTRY[2]

Country	2004 Quantity, gross weight (metric tons)	2004 Value (thousands)	2005 Quantity, gross weight (metric tons)	2005 Value (thousands)
Canada	(3)	$10	--	--
Chile	410	729	654	$1,500
China	--	--	1	20
Czech Republic	(3)	6	--	--
India	--	--	1	32
Mexico	(3)	5	--	--
Spain	4	73	(3)	7
Total	414	824	656	1,560

-- Zero.

[1]Calomel is a mercury-bearing byproduct generated from pollution control equipment using the Norzink process.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 5
MERCURY: WORLD MINE PRODUCTION, BY COUNTRY[1, 2, 3]

(Metric tons)

Country	2001	2002	2003	2004	2005[e]
Algeria	321	307	176	73 [r]	(4)
China[e]	190	435	610	1,140 [r]	1,100
Finland	71	51	25 [r]	24 [r]	65
Kyrgyzstan	300	300	300	300	200
Mexico[e]	15	15	15	15	15
Morocco[e]	10	10 [r]	10 [r]	10 [r]	10
Russia[e]	50	50	50	50	50
Spain	500	300	150	250 [r]	250
Tajikistan[e]	40	20	30	30	30
United States[5]	NA	NA	NA	NA	NA
Total	1,500	1,490	1,370 [r]	1,890 [r]	1,680

[e]Estimated. [r]Revised. NA Not available.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through April 29, 2006.

[3]Canada, Chile, and Peru were believed to produce byproduct mercury, but information on their production was inadequate to make reliable estimates.

[4]Less than ½ unit.

[5]Data on byproduct mercury are not available.

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Mica

By James B. Hedrick

Domestic survey data and tables were prepared by Raymond I. Eldridge III, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

In 2005, about 78,100 metric tons (t) of scrap and flake mica was produced in the United States; this was 21% less than that of 2004 (tables 1, 3). Ground mica sales totaled 120,000 t valued at $47.2 million, an increase in quantity and value compared with 2004 (tables 1, 4). Essentially all sheet mica used in the United States was imported, and India was the major supplier (table 10). Consumption of muscovite block mica decreased to 1.10 t and the value increased to $134,000 in 2005 from 1.81 t valued at $114,000 in 2004 (tables 1, 5). Consumption of mica splittings decreased to 665 t in 2005 from 668 t in 2004 (tables 1, 6). Worked and unworked sheet mica exports increased to 1,420 t in 2005 from 965 t in 2004, and the value increased to $14.2 million in 2005 from $11.2 million in 2004 (table 13). U.S. imports of worked and unworked sheet mica decreased to 1,390 t in 2005 from 1,400 t in 2004, and the value increased to $13.1 million in 2005 from $12.2 million in 2004.

The mica group represents 37 phyllosilicate minerals that have a layered or platy texture (Rieder and others, 1998). Phyllo is derived from the Greek word "phyllon," which means leaf. The commercially important micas are muscovite and phlogopite, which are used in a variety of applications.

Mica's value is based on several of its unique physical properties. The crystalline structure of mica forms layers that can be split or delaminated into thin sheets. These sheets are chemically inert, dielectric, elastic, flexible, hydrophilic, insulating, lightweight, platy, reflective, refractive, resilient, and transparent to opaque. Mica is stable when exposed to electricity, light, moisture, and extreme temperatures. Based on its abundance and superior electrical properties, muscovite is the principal mica used by industry. Phlogopite mica remains stable at higher temperatures and is used in applications in which a combination of high-heat stability and electrical properties is required. Muscovite and phlogopite are used in sheet and ground forms.

Legislation and Government Programs

The Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 (Public Law 108-375) was enacted on October 28, 2004. The Annual Material Plan for Fiscal Year 2005 authorized the disposal of the remaining inventory of mica (all types) from the National Defense Stockpile (NDS) classified as excess to goal. Stocks of mica classified as excess to goal at the end of fiscal year 2004 were all subject to no disposal limits. At the end of fiscal year 2004, NDS mica stocks were 883 kilograms (kg) (1,947 pounds) of muscovite block (stained and better), and 1,508 kg (3,325 pounds) of phlogopite splittings, and stocks of muscovite film (first and second qualities) were sold out. The inventory of mica in the NDS that was sold but not shipped at the end of fiscal year 2004 was 7,195 kg (15,863 pounds) of muscovite block, 120,519 kg (265,700 pounds) of muscovite splittings, and 16,991 kg (37,459 pounds) of phlogopite block.

The National Defense Authorization Act for Fiscal Year 2006 (Public Law 109-163) was enacted on January 6, 2006. Stocks of mica classified as excess to goal at the end of fiscal year 2005 were all subject to no disposal limits. Excess fiscal year 2005 NDS mica stocks authorized for disposal were 97 kg (214 pounds) of muscovite block (stained and better); 7,195 kg (15,863 pounds) of condenser quality muscovite block, which has all been sold (committed inventory); 203 kg (448 pounds) of electronic quality muscovite block, which has been sold (committed inventory); 6,815 kg (15,025 pounds) of muscovite splittings; and 2,723 kg (6,004 pounds) of muscovite splittings, which has been sold (committed inventory). Mica held for goal in the NDS at the end of fiscal year 2005 was 136 kg (300 pounds) of condenser quality muscovite block. Yearend stocks of mica in the NDS as of December 31, 2005, are listed in table 2.

Production

Domestic mine production data for mica are developed by the U.S. Geological Survey from four separate voluntary surveys. Of the 17 operations to which the "Crude Scrap and Flake Mica Production" (including sericite production) survey form was sent, 14 operations responded. Of the 18 operations to which the "Ground Mica" (excluding low-grade ground sericite production) form was sent, 11 operations responded. Of the seven surveyed operations to which the "Mica Block and Film Consumption" form was sent, six operations responded. Of the eight surveyed operations to which the "Mica Splittings Consumption" form was sent, four operations responded. Consumption for the nonrespondents was estimated by using prior-year production data. Individual company production and consumption data are withheld to avoid disclosing company proprietary data.

Georgia Industrial Minerals, Inc. in Sandersville, GA, continued to operate its mine in Deepstep, GA.

A new venture, Deepstep Mineral Products, was under development by David Avant, who was previously the general manager at Georgia Industrial Minerals. The new mine will be located in the area around Deepstep and will be a placer mica operation (David Avant, Deepstep Mineral Products, oral commun., 2006).

Oglebay Norton Company, a Cleveland, OH-based company, announced on April 6 that its Oglebay Norton Specialty Minerals, Inc. subsidiary had completed the sale of the Kings Mountain, NC, mica operation to Kings Mountain Mining LLC (an affiliate of Zemex U.S. Corporation) for $15 million. Zemex U.S. Corporation is based in Atlanta, GA, and is a wholly owned subsidiary of Cementos Pacasmayo SAA of Peru (Olglebay Norton Co., 2005).

On August 22, Zemex Industrial Minerals (ZIM) announced that it had expanded the distribution area of its sales agent Fitz

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Chem Corporation based in Itasca, IL. Fitz acquired the mineral distribution areas of southern Indiana, Kansas, Missouri, and Nebraska. The midwestern distribution and sales area handled by Fitz for ZIM included the States of Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin (Zemex Industrial Minerals, 2005).

Scrap and Flake Mica.—In 2005, eight domestic companies with ten mines in five States produced scrap and flake mica, excluding low-grade sericite. The United States was one of the world's primary producers with production of 78,100 t (tables 1, 3, 14). North Carolina remained the major producing State with 40% of domestic production, and the remainder was produced in Alabama, Georgia, South Carolina, and South Dakota. Mica was recovered from mica schist, high-quality sericite schist, weathered pegmatites, a gemstone pegmatite, and as a coproduct of feldspar and kaolin mining and processing operations. Mining was suspended at Velarde in 2004, which remained on care and maintenance throughout 2005.

The scrap and flake mica producers in 2005 were Engelhard Corp., Hartwell, GA; The Feldspar Corporation (a ZIM company) (two mines), Spruce Pine, NC; Georgia Industrial Minerals, Deepstep, GA; JMays LLC, Micaville, AL; K-T Feldspar Corp., Spruce Pine, NC; Kings Mountain Mining LLC, Kings Mountain, NC; The Mineral Mining Co., Inc., Kershaw, SC; Pacer Corp., Custer, SD; and Unimin Corp., Spruce Pine, NC.

Ground Mica.—In 2005, 8 companies operated 14 grinding plants in 5 States; nine plants produced dry-ground mica, and three, wet-ground mica. The four leading ground mica companies, which included one company with four plants, accounted for 42% of the total of 120,000 t of ground mica produced in the United States (table 4).

Dry-ground mica producers were Asheville Mica Co., Asheville, NC; Engelhard Corp., Hartwell, GA; Georgia Industrial Minerals, Deepstep, GA; JMays LLC, Micaville, AL; K-T Feldspar, Spruce Pine, NC; Kings Mountain Mining LLC, Kings Mountain, NC; The Mineral Mining Co., Inc., Kershaw, SC; Pacer, Custer, SD; Piedmont Minerals Corp., Hillsborough, NC; and United States Gypsum Co. (a subsidiary of USG Corp.), Spruce Pine, NC.

Wet-ground mica producers were Engelhard, Hartwell, GA; Georgia Industrial Minerals, Sandersville, GA; JMays LLC, Micaville, AL; and Kings Mountain Mining LLC, Kings Mountain, NC.

Sheet Mica.—Sheet mica was produced as a byproduct from two mines in 2005. A new mine opened during the year in Alabama.

Small quantities of muscovite sheet and scrap mica were produced as a byproduct by Morefield Gem Mine, Inc. in Amelia County, VA. The pegmatite was mined primarily for gemstones and mineral specimens using underground methods. The mine also produced biotite and zinnwaldite mica.

The Micaville #1 Mine in Micaville was owned and operated by JMays. The mine produced small amounts of muscovite sheet mica as a byproduct of scrap and flake mica for dry- and wet-grinding.

Consumption

Ground Mica.—The leading domestic use of dry-ground mica was in joint compound for filling and finishing seams and blemishes in gypsum wallboard (drywall) (table 4). The mica acts as a filler and extender, provides a smooth consistency, improves the workability of the compound, and provides resistance to cracking. In 2005, joint compound accounted for 52% of dry-ground mica consumption.

In the paint industry, ground mica is used as a pigment extender that also facilitates suspension, reduces chalking, prevents shrinking and shearing of the paint film, increases resistance of the paint film to water penetration and weathering, and brightens the tone of colored pigments. Mica also promotes paint adhesion in aqueous and oleoresinous formulations. Consumption of dry-ground mica in paint, the second ranked use, accounted for 12% of the dry-ground mica used in 2005.

Ground mica is used in the well-drilling industry as an additive to drilling muds. The coarsely ground mica flakes help prevent the loss of circulation by sealing porous sections of the drill hole. Well drilling muds accounted for less than 4% of dry-ground mica use.

The plastics industry used dry-ground mica as an extender and filler, especially in parts for automobiles for lightweight insulation to suppress sound and vibration. Mica is used in plastic automobile fascia and fenders as a reinforcing material, providing improved mechanical properties and increased dimensional stability, stiffness, and strength. Mica-reinforced plastics also have high-heat dimensional stability, reduced warpage, and the best surface properties of any filled plastic composite. In 2005, consumption of dry-ground mica in plastic applications accounted for 3.1% of the market.

The rubber industry used ground mica as an inert filler and a mold release compound in the manufacture of molded rubber products, such as tires and roofing. The platy texture acts as an antiblocking, antisticking agent. Rubber mold lubricant accounted for 1.2% of the dry-ground mica used in 2005.

Dry-ground mica is used in the production of rolled roofing and asphalt shingles where it serves as a surface coating to prevent sticking of adjacent surfaces. The coating is not absorbed by freshly manufactured roofing because mica's platy structure is unaffected by the acid in asphalt or by weathering conditions. As a rubber additive, mica reduces gas permeation and improves resiliency.

Mica is used in decorative coatings on wallpaper, concrete, stucco, and tile surfaces. It also is used as an ingredient in flux coatings on welding rods, in some special greases, and as coatings for core and mold release compounds, facing agents, and mold washes in foundry applications.

Dry-ground phlogopite mica is used in automotive brake linings and clutch plates to reduce noise and vibrations (asbestos substitute); as sound-absorbing insulation for coatings and polymer systems; reinforcing additives for polymers to increase strength and stiffness and to improve stability to heat, chemicals, and ultraviolet (UV) radiation; heat shields and temperature insulation; industrial coating additive to decrease the permeability of moisture and hydrocarbons; and in polar polymer formulations to increase the strength of epoxies, nylons, and polyesters.

Wet-ground mica, which retains the brilliancy of its cleavage faces, is used primarily in pearlescent paints by the automotive industry. In the cosmetics industry, its reflective and refractive properties made mica an important ingredient in blushes, eyeliner, eyeshadow, foundation, hair and body glitter, lipstick, lip gloss, mascara, moisturizing lotions, and nail polish. Mica is added to latex balloons to provide a colored shiny surface.

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Natural mica is used by Taos and Picuris Pueblos in north-central New Mexico in making pottery. The pottery is made from weathered pre-Cambrian mica schist and has flecks of mica throughout the vessels. The Tewa Pueblo pottery is made by coating the clay with mica to provide a dense-glittery micaceous finish over the entire object.

Built-Up Mica.—Muscovite and phlogopite splittings were fabricated into various built-up mica products by nine companies that operated nine plants in seven States. Produced by mechanized or hand setting of overlapping splittings and alternate layers of binders and splittings, built-up mica is used primarily as an electrical insulation material. Mica insulation is used in high-temperature and fire-resistant power cable used in aluminum plants, blast furnaces, critical wiring circuits (for example, defense systems, fire and security alarm systems, and surveillance systems), heaters and boilers, lumber kilns, and metal smelters, and tanks and furnace wiring. Specific high-temperature mica-insulated wire and cable is rated to work for up to 15 minutes in molten aluminum, glass, and steel. Major products are bonding materials; flexible, heater, molding, and segment plates; mica paper; and tape (table 7).

Flexible plate (cold) is used in electric motor and generator armatures, field coil insulation, and magnet and commutator core insulation. Mica consumption in flexible plate in 2005 was 73 t, essentially unchanged from 2004.

Heater plate is used where high-temperature insulation is required. Consumption data for mica in heater plate are withheld to avoid disclosing company proprietary information. Consumption of heater plate mica decreased in 2005 compared with that of 2004.

Molding plate is sheet mica from which V-rings are cut and stamped for use in insulating the copper segments from the steel shaft ends at the end of a commutator. Molding plate is also fabricated into tubes and rings for insulation in armatures, motor starters, and transformers. Consumption of molding plate in 2005 was 185 t, unchanged from the previous year.

Segment plate acts as insulation between the copper commutator segments of direct-current universal motors and generators. Phlogopite built-up mica is preferred because it will wear at the same rate as the copper segments. Although muscovite has a greater resistance to wear, it causes uneven ridges that may interfere with the operation of a motor or generator. Consumption of segment plate was 220 t in 2005.

Some types of built-up mica have the bonded splittings reinforced with cloth, glass, linen, muslin, plastic, silk, or special paper. These products are very flexible and are produced in wide, continuous sheets that are either shipped rolled or cut into ribbons, tapes, or trimmed to specified dimensions. Built-up mica products may also be corrugated or reinforced by multiple layering.

In 2005, the total amount of built-up mica that was consumed or shipped was 558 t, essentially the same level as the amount for 2004 (559 t). Molding plate and segment plate were the major end products and accounted for 33% and 39% of the total, respectively.

Mica Paper (Reconstituted Mica).—Primary uses for mica paper are the same as those for built-up mica. Three companies consumed scrap mica to produce mica paper for electrical applications. The principal source of the scrap was India. In 2005, the manufacturing companies were Asheville-Schoonmaker Mica Co., Newport News, VA; Corona Films Inc., West Townsend, MA; and Isovolta Inc./US Samica Corp., Rutland, VT.

Sheet Mica.—Sheet mica is used principally in the electronic and electrical industries. Its usefulness in these applications is derived from its unique electrical and thermal insulating properties and its mechanical properties, which allow it to be cut, punched, stamped, and machined to close tolerances.

The leading use of block mica is as an electrical insulator in electronic equipment. High-quality block mica is processed to line the gauge glasses of high-pressure steam boilers because of its flexibility, transparency, and resistance to heat and chemical attack. Other uses include diaphragms for oxygen-breathing equipment, marker dials for navigation compasses, optical filters, pyrometers, retardation plates in helium-neon lasers, thermal regulators, and stove and kerosene heater windows. Specialized applications for sheet mica are found in aerospace components in ground- and air-launched missile systems, laser devices, medical electronics, optical instrumentation, radar systems, radiation detector windows that are transparent to alpha emissions (Geiger-Mueller tubes), and for radiation treatment.

Only high-quality muscovite film mica, which is variously called India ruby mica or ruby muscovite mica, is used as a dielectric in capacitors. The highest quality film is used to manufacture capacitors for calibration standards. The next lower grade is used in transmitting capacitors. Receiving capacitors use a slightly lower grade of high-quality muscovite.

In 2005, consumption of ruby and nonruby muscovite block totaled 1.10 t, a decrease from the 1.81 t consumed in 2004 (table 5). Stained and lower-than-stained quality remained in greatest demand and accounted for about 59% of consumption of ruby and nonruby mica block. Consumption of nonruby mica block was 56.4% for stained and lower-than-stained quality and 43.6% for good quality.

In 2005, five companies consumed muscovite block and film at five plants in four States—two in North Carolina and one each in New Jersey, Ohio, and Virginia.

In 2005, mica splittings represented the largest part of the sheet mica industry in the United States. Consumption of muscovite and phlogopite splittings was 665 t in 2005 compared with 668 t in 2004 (table 6). Muscovite splittings from India accounted for essentially all domestic consumption. The remainder was primarily imported from Madagascar.

Stocks

Reported yearend industry stocks of muscovite mica block (ruby and nonruby) increased to 19.6 t in 2005 from 17.3 t in 2004. Industry stocks of muscovite and phlogopite mica splittings decreased to 408 t at yearend 2005 from 416 t at yearend 2004 (table 6).

Prices

Sheet mica prices vary with grade and can range from less than $1 per kilogram for low-quality mica to more than $2,000 per kilogram for the highest quality. The average values of mica block and splittings consumed in the United States in 2005 compared with those of 2004 were as follows: muscovite block (ruby and nonruby)

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increased to $125 per kilogram from $63 per kilogram, muscovite and phlogopite splittings were unchanged at $1.73 per kilogram, and muscovite and phlogopite block increased by $5 per kilogram to $72 per kilogram (tables 1, 6). Phlogopite block increased to $142 per kilogram from $98 per kilogram, and phlogopite splittings increased slightly to $4.66 per kilogram from $4.63 per kilogram.

In 2005, the average U.S. value of scrap and flake mica, which included high-quality sericite, increased to $247 per metric ton (table 3). The average value for North Carolina flake mica increased to $265 per ton. The average value of dry-ground mica decreased to $205 per ton, and the average value of wet-ground mica was $704 per ton (table 1).

Foreign Trade

The value of U.S. exports of mica increased by 17.7% to $19.7 million, and the quantity decreased by 1.2% to 10,800 t (tables 1, 13). U.S. exports of mica excluding unworked mica scrap increased by 18.8% in value from those of 2004 to $19.4 million, and the quantity increased by 4.6% to 10,000 t.

Domestic ground mica (powder) exports decreased to 7,140 t, a decrease of 60 t from that of 2004 (tables 8, 13). Exports of crude and rifted mica decreased by 40.1% to 787 t from 1,310 t exported in 2004, and their value increased by 23.4% to $541,000 in 2005 from $438,000 in 2004 (tables 9, 13).

The value of U.S. imports of all mica decreased by 3.8% to $26.3 million, and the quantity decreased by 11.6% to 38,800 t. U.S. imports of mica excluding unworked mica scrap (less than $1.00 per kilogram) decreased by 0.3% in value from those of 2004 to $23.5 million and by 5.6% in quantity to 23,700 t.

India continued to supply the United States with essentially all its supply of sheet and paper-quality scrap micas. Total imports for consumption of unworked split block, film, splittings, and mica sheet categorized as "Other" totaled about 15,100 t in 2005 (table 10). Imports of unworked low-value scrap mica (less than $1.00 per kilogram) decreased to 15,000 t in 2005 compared with 18,700 t in 2004 (table 10). Demand weakened for the low-value mica for use as a dry-ground additive for drywall compound, fillers, and paints.

In 2005, 21,400 t of powder mica was imported, mostly from Canada, about 900 t less than in 2004 (table 11). Worked mica imports were 1,340 t; this was 4.7% higher than those of 2004 (table 12).

Outlook

The outlook for ground mica is for production growth of 1% to 3% per year for the next decade. The major markets for ground mica—drywall joint compounds and paints—are mature and relatively stable with growth tied to new housing starts and interest rates. To a lesser extent, widespread natural disasters, such as hurricanes and flooding, also affect the market by creating immediate demand for residential building materials. Demand is also affected by automobile production because interior and exterior parts typically contain dry-ground mica or engineered mica composites and exterior surfaces are painted with wet-ground pearlescent pigments and mica-containing coatings.

Domestic demand for crude and ground mica in 2006 and 2007 was expected to increase slowly. Demand for wet-ground mica used in pearlescent automotive coatings and dry-ground mica used in automotive fillers and plastics was also expected to increase slowly. Demand for ground mica in such smaller specialty markets as coated micas, cosmetics, nylon and polyester resins, and polypropylene composites was expected to increase at a rate slightly higher than the 1% to 3% production rate. Consumption of dry-ground mica was expected to increase by as much as 2% to 3% per year through 2007 unless higher interest rates and significantly higher home prices slow the increase in demand for new housing. Increasing fuel prices were expected to reduce demand for automobiles. Wet-ground mica was expected to show a moderate 2% to 3% growth through 2020 as demand from the automotive industry increases in response to population growth and as use of pearlescent paints and engineered mica-bearing plastics and composites increases.

Demand for block mica was expected to increase slowly at about 1% per year during the next several years as demand increases in a few specialty markets, such as electronics. A shortage of high-quality block mica was expected to continue because of the generally low percentage of high-quality mica in currently mined deposits, mostly pegmatites.

Consumption of mica splittings, which is the principal type of sheet mica consumed in the United States, has been in the range of 700 to 1,000 metric tons per year (t/yr). With no potential new uses apparent and many substitute materials being used, no substantial growth is expected. Consumption of mica splittings was expected to remain in the range of 500 to 900 t/yr in the near future.

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TABLE 1
SALIENT MICA STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Production, sold or used by producers:						
Scrap and flake mica:						
Quantity	thousand metric tons	98	81	79	99	78
Value	thousands	$7,990	$7,370	$16,700	$15,400	$19,300
Ground mica:						
Quantity	thousand metric tons	89	99	94	98	120
Value	thousands	$28,100	$29,600	$28,600	$27,200	$47,200
Prices:						
Scrap and flake mica	dollars per metric ton	82	90	213	155	247
Ground:						
Wet	do.	771	960	938	NA	704
Dry	do.	147	180	205	269	205
Sheet, muscovite and phlogopite:						
Block	dollars per kilogram	55	67	67	67	72
Splittings	do.	1.67	1.82	1.74	1.73	1.73
Consumption:						
Block, muscovite:						
Quantity	metric tons	3	2	2	2	1
Value	thousands	$129	$134	$120	$114	$134
Splittings, all types						
Quantity	metric tons	742	573	669	668	665
Value	thousands	$1,240	$1,040	$1,160	$1,150	$1,150
Exports	metric tons	10,500	10,500	11,200	10,900	10,800
Imports	do.	36,600	36,400	36,000	43,800	38,800
World, production	do.	368,000	269,000	271,000 r	319,000 r, e	294,000 e

eEstimated. rRevised. NA Not available.

[1]Data are rounded to no more than three significant digits.

TABLE 2
STOCKPILE STATUS AND GOVERNMENT INVENTORIES FOR MICA, DECEMBER 31, 2005

(Metric tons)

	Inventory, uncommitted			
Material	Stockpile grade	Nonstockpile grade	Available for disposal	Fiscal year 2005 sales
Block:				
Muscovite:				
Stained and better	(1)	--	(2)	(3)
Stained and lower	--	--	(2)	(3)
Phlogopite	--	--	(2)	--
Film, muscovite (first and second qualities)	--	--	(2)	--
Splittings:				
Muscovite	7	--	(2)	7
Phlogopite	--	--	(2)	2

-- Zero.

[1]Less than ½ unit.

[2]The total disposal plan for all categories of mica in the national stockpile is undifferentiated at 453.592 metric tons (1 million pounds).

[3]Fiscal year 2005 sales for muscovite block is undiffentiated at 35.687 metric tons (78,676 pounds).

Source: Defense National Stockpile Center.

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TABLE 3
SCRAP AND FLAKE MICA SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars)

State	2004		2005	
	Quantity	Value	Quantity	Value
North Carolina	40	9,600	39	10,200
Other[3]	59	5,750	40	9,070
Total	99	15,400	78	19,300

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes finely divided mica recovered from mica schist and high-quality sericite schist, and mica that is a byproduct of feldspar and kaolin beneficiation.

[3]Includes Alabama, Georgia, South Carolina, and South Dakota.

TABLE 4
GROUND MICA SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY END USE AND METHOD OF GRINDING[1, 2]

	2004			2005		
	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
End use:						
Joint cement	53	$11,600	$219	63	$15,000	$238
Paint	18	8,370	453	14	4,550	328
Plastics	5	2,470	463	4	2,070	518
Well-drilling mud	(3)	(3)	413	(3)	(3)	148
Other[4]	21	4,720	220	39	25,600	654
Total	98	27,200	276	120	47,200	393
Method of grinding:						
Dry	W	W	269	W	W	205
Wet	W	W	NA	W	W	704

NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Domestic and some imported scrap. Low-quality sericite is not included.

[3]Withheld to avoid disclosing company proprietary data; included in "Other."

[4]Includes mica used for molded electrical insulation, roofing, rubber, textile and decorative coatings, welding rods, and miscellaneous.

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TABLE 5
FABRICATION OF MUSCOVITE BLOCK MICA
IN THE UNITED STATES, BY QUALITY[1]

(Metric tons)

	2004	2005
Good stained or better	0.48	0.44
Stained or lower than stained[2]	1.33	0.65
Total	1.81	1.10

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes punch mica.

TABLE 6
CONSUMPTION AND STOCKS OF MICA SPLITTINGS
IN THE UNITED STATES[1]

	Consumption		Stocks on
	Quantity	Value	December 31
Year	(metric tons)	(thousands)	(metric tons)
2004	668	$1,150	416
2005	665	1,150	408

[1]Data are rounded to no more than three significant digits.

TABLE 7
BUILT-UP MICA SOLD OR USED IN THE UNITED STATES, BY PRODUCT[1, 2]

	2004		2005	
	Quantity	Value	Quantity	Value
	(metric tons)	(thousands)	(metric tons)	(thousands)
Flexible plate (cold)	73	$354	73	$354
Heater plate	W	W	W	W
Molding plate	185	1,330	185	1,330
Segment plate	220	1,140	220	1,140
Tape	W	W	W	W
Other	81	557	80	555
Total	559	3,380	558	3,390

W Withheld to avoid disclosing company proprietary data; included in "Other."
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Consists of alternating layers of binder and irregularly arranged and partly overlapped splittings.

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TABLE 8

U.S. EXPORTS OF CRUDE AND RIFTED MICA, MICA POWDER, AND WASTE IN 2005, BY COUNTRY[1]

	Crude and rifted							
	Less than $1 per kilogram		More than $1 per kilogram		Powder		Waste	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	8	$13	--	--	6	$21	--	--
Australia	--	--	--	--	4	5	--	--
Bahamas, The	--	--	41	$116	--	--	--	--
Barbados	--	--	--	--	5	3	--	--
Belgium	--	--	2	10	284	203	--	--
Brazil	11	4	(2)	4	263	158	--	--
Canada	33	11	--	--	3,450	1,870	1,410	$328
Chile	--	--	6	6	--	--	--	--
China	9	3	--	--	317	153	--	--
Colombia	22	6	--	--	97	55	--	--
Ecuador	--	--	--	--	3	15	--	--
El Salvador	10	4	--	--	17	9	--	--
France	--	--	--	--	102	186	62	13
Germany	34	12	--	--	244	146	--	--
Guatemala	--	--	2	7	--	--	--	--
Honduras	--	--	(2)	3	--	--	--	--
Hong Kong	--	--	--	--	26	100	--	--
India	169	41	--	--	44	8	--	--
Indonesia	--	--	--	--	11	10	--	--
Ireland	8	3	--	--	16	4	--	--
Israel	--	--	1	8	--	--	--	--
Italy	--	--	--	--	99	25	--	--
Japan	--	--	1	9	453	310	--	--
Korea, Republic of	--	--	--	--	356	299	--	--
Mexico	197	69	--	--	465	300	--	--
Netherlands	184	98	9	17	650	716	--	--
Pakistan	--	--	--	--	14	22	--	--
Panama	--	--	2	10	--	--	--	--
Peru	--	--	--	--	(2)	3	--	--
Philippines	--	--	--	--	16	20	--	--
Poland	--	--	--	--	9	4	--	--
Saudi Arabia	--	--	--	--	35	16	--	--
Singapore	--	--	11	79	4	4	7	3
South Africa	--	--	--	--	10	3	--	--
St. Lucia	--	--	--	--	16	20	--	--
Switzerland	--	--	--	--	(2)	7	--	--
Taiwan	--	--	--	--	6	27	--	--
Thailand	39	24	--	--	4	18	--	--
Trinidad and Tobago	--	--	--	--	(2)	9	--	--
United Arab Emirites	--	--	--	--	14	16	--	--
United Kingdom	--	--	--	--	100	100	--	--
Venezuela	--	--	--	--	4	6	--	--
Total	713	272	74	269	7,140	4,860	1,480	343

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 9

U.S. EXPORTS OF WORKED MICA IN 2005, BY COUNTRY[1]

Country	Plates, sheets		Other	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	21	$305	(2)	$7
Australia	87	530	12	34
Austria	(2)	3	205	1,410
Bahamas, The	(2)	3	4	28
Barbados	--	--	6	26
Belgium	2	26	1	16
Brazil	28	594	1	37
Canada	97	2,440	117	1,860
Cayman Islands	1	12	(2)	11
Chile	(2)	3	--	--
China	10	159	9	181
Colombia	2	60	(2)	12
Costa Rica	1	8	--	--
Czech Republic	(2)	3	--	--
Ecuador	--	--	2	18
El Salvador	1	4	--	--
France	68	363	(2)	3
Germany	15	139	1	58
Honduras	3	11	--	--
Hong Kong	2	18	--	--
Iceland	2	12	--	--
India	--	--	(2)	3
Ireland	38	122	--	--
Israel	6	42	--	--
Italy	8	151	3	47
Japan	9	88	50	350
Kazakhstan	--	--	(2)	3
Korea, Republic of	27	562	--	--
Malaysia	2	41	--	--
Mexico	17	402	16	483
Namibia	--	--	(2)	4
Netherlands	9	72	--	--
New Zealand	(2)	11	--	--
Pakistan	--	--	(2)	3
Panama	--	--	1	3
Poland	--	--	(2)	8
Romania	--	--	(2)	3
Singapore	1	81	(2)	28
South Africa	(2)	12	--	--
Sri Lanka	4	11	--	--
Switzerland	1	27	(2)	7
Taiwan	92	599	18	562
Trinidad and Tabago	1	18	--	--
United Arab Emirates	--	--	3	19
United Kingdom	20	316	(2)	8
Venezuela	318	1,410	--	--
Vietnam	7	27	--	--
Total	901	8,680	450	5,230

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF CRUDE AND RIFTED MICA IN 2005, BY COUNTRY[1]

	Split block		Splittings		Other			
					Less than $1 per kilogram		More than $1 per kilogram	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Canada	--	--	--	--	58	$10	--	--
China	--	--	--	--	6,290	784	8	$99
Finland	--	--	--	--	340	107	--	--
Germany	--	--	--	--	151	43	--	--
Hong Kong	--	--	--	--	--	--	4	39
India	(2)	$13	40	$26	8,190	1,830	1	22
Korea, Republic of	--	--	--	--	--	--	(2)	4
Total	(2)	13	40	26	15,000	2,770	13	163

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 11
U.S. IMPORTS FOR CONSUMPTION OF MICA POWDER AND WASTE IN 2005, BY COUNTRY[1]

	Powder		Waste	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Argentina	521	$437	--	--
Australia	1	7	--	--
Canada	15,300	5,480	253	$55
China	4,600	827	--	--
France	16	92	--	--
Germany	13	93	--	--
India	291	106	646	310
Italy	8	13	--	--
Japan	499	2,850	--	--
Malaysia	12	26	--	--
Norway	208	126	--	--
United Kingdom	2	21	--	--
Total	21,400	10,100	900	365

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF WORKED MICA IN 2005, BY COUNTRY[1]

	Plates, sheets		Other	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Austria	128	$2,820	7	$178
Belgium	292	3,870	--	--
Brazil	332	939	--	--
Canada	3	57	(2)	5
China	125	347	36	258
Czech Republic	(2)	4	(2)	4
France	26	213	3	133
Germany	27	625	19	72
Hong Kong	--	--	11	88
India	28	528	169	861
Indonesia	(2)	3	--	--
Japan	8	228	20	218
Korea, Republic of	3	45	40	62
Netherlands	1	15	--	--
Romania	(2)	4	--	--
Singapore	--	--	(2)	8
Switzerland	40	668	(2)	8
Taiwan	--	--	1	7
United Kingdom	2	116	16	485
Total	1,020	10,500	321	2,380

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 13

SUMMATION OF U.S. MICA TRADE DATA[1]

	Scrap and flake mica				Sheet mica			
	Powder		Waste		Unworked		Worked	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Exports:								
2004	7,200	$4,780	2,730	$731	29	$58	935	$11,100
2005	7,140	4,860	2,190	615	74	269	1,350	13,900
Imports for consumption:								
2004	22,300	10,800	20,100	4,410	124 [2]	358 [2]	1,280	11,800
2005	21,400	10,100	15,900	3,140	53 [2]	175 [2]	1,340	12,900

[1]Data are rounded to no more than three significant digits.

[2]Excludes unworked sheet mica valued at less than $1 per kilogram.

Source: U.S. Census Bureau.

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TABLE 14

MICA: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004[e]	2005[e]
Argentina, all grades	2,120	1,770	1,894	2,178 [r, 4]	2,200
Brazil[e]	4,000	4,000	5,000 [r]	5,000 [r]	5,000
Canada[e]	17,500	17,500	17,500	17,500	17,500
France[e]	10,000	10,000	10,000	10,000	10,000
India:					
Crude	1,300	1,500	1,600 [e]	1,600	1,600
Scrap and waste	1,100	2,000	2,000 [e]	2,100 [r]	2,100
Total	2,400	3,500	2,600 [e]	3,700 [r]	3,700
Iran[5]	3,255	2,845	5,500 [r]	7,032 [r, 4]	7,000
Korea, Republic of, all grades	109,339	29,870	33,645	59,238 [r, 4]	50,000
Madagascar, phlogopite	90	60	70 [e]	70	70
Malaysia	4,107	3,669	3,609	3,544 [r, 4]	3,600
Mexico, all grades	648	456	506	424 [r]	450
Norway, flake[e]	2,500	2,600	2,600	2,600	2,700
Russia[e]	100,000	100,000	100,000	100,000	100,000
Serbia and Montenegro[e]	100	100	100	100	100
South Africa, ground and scrap	937	821	1,003	901 [4]	941 [4]
Spain[e]	2,500	2,500	2,500	2,500	2,500
Sri Lanka, scrap	1,161	1,161	1,674 [r]	1,700 [r]	1,700
Taiwan	9,733	6,595	3,237	2,979 [4]	8,608 [4]
United States, scrap and flake[6]	97,800	81,100	78,600	99,200 [4]	78,100 [4]
Grand total	368,000	269,000	271,000 [r]	319,000 [r]	294,000

[e]Estimated. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through May 30, 2006.

[3]In addition to the countries listed, China, Pakistan, Romania, and Sweden are known to produce mica, but available information is inadequate to make reliable estimates of output levels.

[4]Reported figure.

[5]Year beginning March 21 of that stated.

[6]Excludes, if any, U.S. production of low-quality sercite and sheet mica.

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MOLYBDENUM

By Michael J. Magyar

Domestic survey data and tables were prepared by Cindy C. Chen, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

Molybdenum is a refractory metallic element used principally as an alloying agent in cast iron, steel, and superalloys to enhance hardenability, strength, toughness, and wear- and corrosion- resistance. To achieve desired metallurgical properties, molybdenum, primarily in the form of molybdic oxide (MoX) or ferromolybdenum (FeMo), is frequently used in combination with or added to chromium, columbium (niobium), manganese, nickel, tungsten, or other alloy metals. The versatility of molybdenum in enhancing a variety of alloy properties has ensured it a significant role in contemporary industrial technology, which increasingly requires materials that are serviceable under high stress, expanded temperature ranges, and highly corrosive environments. Moreover, molybdenum finds significant use as a refractory metal in numerous chemical applications, including catalysts, lubricants, and pigments. The variety of uses for molybdenum materials, few of which afford acceptable substitution, has resulted in an increase in Western molybdenum consumption to an estimated 160,000 metric tons per year (t/yr) [352 million pounds per year (Mlb/yr)] in 2005 (Adams, 2005) from about 68,000 t/yr (150 Mlb/yr) in 1983 (Adams, 2004).

Molybdenum reserves and production capacity were concentrated in a few countries of the world. World mine output was estimated to be 185,000 metric tons (t) (molybdenum contained in concentrate), of which, in descending order of production, the United States, Chile, China, Peru, Canada, and Mexico provided about 95% (table 11). Chile, China, and the United States also held about 85% of the estimated 19 million metric tons (Mt) of molybdenum in the world reserve base.

Production

Domestic production data for molybdenum were derived from three separate voluntary surveys by the U.S. Geological Survey. These surveys are "Molybdenum Ore and Concentrate" (annual), "Molybdenum Concentrate" (monthly), and "Molybdenum Products and Molybdenum Concentrates" (monthly). Surveys were sent to all eight operations that produce molybdenum ore and products, and all responded, representing 100% of the U.S. production listed in table 1.

In 2005, U.S. mine production of molybdenum concentrate was 58,000 t, about a 40% increase from 41,500 t in 2004. World mine production of molybdenum in 2005 increased to 185,000 t, about a 16% increase from 159,000 t (revised) in 2004. The U.S. share of world production was about 31% in 2005. Net production of molybdenum products increased to 29,800 t in 2005 from 24,300 t in 2004 (table 2).

Primary molybdenum production continued at the Henderson Mine in Colorado, the Questa Mine in New Mexico, and the Thompson Creek Mine in Idaho. The Climax Mine in Colorado has been inactive since 1995. Molybdenum was produced as a byproduct of copper production at the Bagdad and Sierrita Mines in Arizona, the Continental Pit in Montana, the Chino Mine in New Mexico, and the Bingham Canyon Mine in Utah. Montana Resources' Continental Pit in Montana resumed operation in November 2003 and made the first shipments of molybdenite concentrate in early 2004 (Platts Metals Week, 2003). The byproduct molybdenum recovery circuit at Phelps Dodge's Chino Mine was restarted in the fourth quarter and produced a minor amount of concentrate in 2004.

With byproduct molybdenum recovery at a copper mine, all mining costs associated with producing the molybdenum concentrate are allocated to the primary metal (copper). Owing to this cost advantage, byproduct molybdenite recovery from copper circuits at selected porphyry copper mines was estimated to account for 56% of the United States and 63% of worldwide molybdenum supply in 2005. Kennecott Utah Copper increased byproduct molybdenum production by more than 240%, and Montana Resources increased production by about 27% as compared with that of 2004. Phelps Dodge Corp. byproduct production was about equal to that of 2004.

Primary molybdenum mines operate in a swing capacity and have a limited ability to change production rate to meet spikes in demand. Phelps Dodge Corp. increased primary molybdenum recovery by about 20% through development work at its Henderson Mine, and Thompson Creek increased production by about 90% in 2005, reaping the benefits of mine development done the previous year. The Questa Mine continued to operate its mine and mill separately at intervals of about 2 to 3 months. Phelps Dodge Corp. commissioned two 6-month studies to determine the economic feasibility of reopening its Climax Mine; however, resumption of mining would not take place before 2008. If reopened, the mine could produce between 4,500 to 9,000 t/yr (10- to 20-million pounds per year) (Ryan's Notes, 2005f).

Golden Phoenix Minerals, Inc. received Notice of Final Decision on October 15, 2005, from the Nevada Division of Environmental Protection, related to its water pollution control and reclamation permits. The company began construction of a 100-standard-ton-per-day flotation mill in November and will process a 1,000-t bulk sample early in 2006 to prove process design and test market the molybdenum concentrates produced (Golden Phoenix Minerals Inc., 2005§[1]).

In May 2005, the board of directors of Quadra Mining Ltd. approved $7.75 million for construction of a molybdenum recovery circuit at its Robinson Mine near Ely, Nevada. Quadra also equipped a lab at the mine to allow molybdenum assays to be run onsite for mill feed and copper concentrates. Production was expected to be from 450 to 725 t of molybdenum in concentrate in 2006 at an estimated operating cost of $2.50 per pound (Quadra Mining Ltd., 2006§).

[1]References that include a section mark (§) are found in the Internet References Cited section.

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Consumption

In 2005, reported consumption (roasting) of molybdenum concentrate was 46,600 t, an increase of about 7,900 t compared with that of 2004. The increase resulted from increased mine production and because domestic roasters were ramped up to full capacity in 2005. Domestic mine production of molybdenum concentrate was roasted, exported for conversion, or purified to lubricant-grade molybdenum disulfide. Technical-grade MoX consumption in 2005 was about 9.5% greater than that of 2004. Oxide was the chief form of molybdenum used by industry, particularly in making full alloy, stainless and tool steel, and superalloys; however, some of the oxide was converted to other molybdenum products, such as ammonium and sodium molybdates, FeMo, high-purity oxide, and metal powder (table 3).

Metallurgical applications continued to dominate molybdenum use in 2005, accounting for about 84% of total consumption (table 3). In 2005, ferromolybdenum accounted for about 41% of the molybdenum-bearing materials used to make steel, a 3% increase from that of 2004. Nonmetallurgical applications included catalysts, chemicals, lubricants, and pigments. The dominant nonmetallurgical use was in catalysts.

Stocks

At yearend, 2005 producer plus consumer industry stocks contained about 5,800 t of molybdenum, an increase of about 1,200 t compared with those at yearend 2004. Inventories of molybdenum in concentrate at mines and plants increased by about 1,000 t. Producer stocks of molybdenum in such products as FeMo, molybdates, MoX, metal powders, and other types increased by about 930 t compared with those of 2004. Total stocks of about 9,410 t represented about a 26-week supply. Supply was calculated as reported stocks divided by annual consumption (table 1).

Prices

Prices were reported in Platts Metals Week in dollars per kilogram (kg) of contained molybdenum. The annual time-average prices for 2005 were MoX, $70.677 per kg and FeMo, $81.539 per kg of contained molybdenum, which represented increases of 92% and 102%, respectively, compared with 2004 prices. Molybdenum prices rose slightly in January, relative to their December 2004 levels, to $70.396 and $81.433, respectively, but dropped to $61.812 and $76.059 in February. Prices rose steadily from March through May and reached their highest point in June at $82.232 and $91.712, respectively. Prices followed a generally downward trend the rest of the year to close at $61.840 and $70.989, respectively. The MoX monthly average price ranged from the low of $61.812 per kg in February to a high of $82.832 per kg in June, and the FeMo monthly average price ranged from a low of $70.989 per kg in December to the high of $91.712 per kg in June.

Foreign Trade

In 2005, molybdenum-containing material exports collectively contained about 48,500 t of molybdenum and were valued at $2.06 billion (table 6). Imports for consumption of molybdenum-containing materials (products) collectively were valued at $1.2 billion (table 9).

World Industry Structure

Capacity.—As of December 31, 2004, U.S.-rated capacity, for mines and mills, was estimated to be about 75,000 t/yr of contained metal. Rated capacity was defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate based on the physical equipment of the plant and given acceptable routine operating procedures involving energy, labor, maintenance, and materials. Capacity included operating plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimal capital expenditure.

Reserves.—The U.S. molybdenum reserve base was estimated to be about 5.4 Mt, about 28% of the world molybdenum reserve base. About 90% of U.S. reserves occur in large low-grade porphyry molybdenum deposits mined or anticipated to be mined primarily for molybdenum and as an associated metal sulfide in low-grade porphyry copper deposits. These deposits were in Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, and Utah. Other molybdenum sources contribute insignificantly to U.S. reserves.

Most Canadian reserves of molybdenum were contained in porphyry molybdenum and porphyry copper-molybdenum deposits in British Columbia. Other Canadian reserves were associated with minor copper-molybdenum porphyry deposits in New Brunswick and Quebec.

Molybdenum reserves in Central America and South America were associated mainly with large copper porphyry deposits. Of several such deposits in Chile, the Chuquicamata and El Teniente deposits were among the world's largest and accounted for 85% of molybdenum reserves in Chile. Peru also had substantial reserves, and the La Caridad deposit in Mexico was a leading producer. Numerous other porphyry copper deposits that may contain recoverable quantities of molybdenum have been identified in Central America and South America. Many of these deposits were being actively explored and evaluated and could substantially add to reserves in the future. Reserves of molybdenum in China and the Commonwealth of Independent States were thought to be substantial, but definitive information about the current sources of supply or prospects for future development in these two areas was lacking.

World Review

European Union.— The European Confederation of Iron and Steel Industries (Eurofer) finalized a resolution in June asking the European Union either to conduct an interim review of the antidumping tariff on Chinese origin FeMo imports or to temporarily suspend the duty. A 5-year sunset review of the duty would not take place until February 2007. A duty of 22.5% was placed on Chinese-origin FeMo by the European Commission in January 2002 after a finding that dumping of Chinese material had caused harm to the European FeMo industry. Specialty steelmakers continued to be adversely

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affected by the high prices and limited supply of molybdenum in 2005 (Ryan's Notes, 2005a).

Treibacher Industrie AG announced that it would continue to produce FeMo at full capacity, contrary to rumors that it intended to discontinue production. Treibacher intended to cease production of a specialty grade of FeMo called Molyquik as it found the product difficult to market. Treibacher began producing Molyquik in 2001 and was producing only 2,500 t/yr but had a capacity of 6,500 t/yr (Ryan's Notes, 2005b).

Armenia.—Zangezur Copper-Molybdenum CJSC expanded operations in the Karajan copper-molybdenum field, the largest molybdenum-bearing deposit in the former Soviet Union. All molybdenum concentrates produced by the Zangezur plant were processed in Armenia, primarily by Armenian Pure Iron Works (API) and Armenian Molybdenum Production CJSC (AMP). API produced about 3,000 t of FeMo, 58% more than that of 2004, and AMP produced about 1,500 t of FeMo, about 180% more than that of 2004. Germany's Cronimet Mining GmbH, which owns 60% of Zangezur and 51% of API, was the principal buyer of the finished molybdenum products (Metal-Pages, 2005§).

Canada.— Molybdenum production was restarted at the Gibraltar Mine in British Columbia in February. After 4 months of preproduction mining and mill/plant refurbishment, Gibraltar restarted copper milling operations in October 2004. A $1.5 million upgrade of the molybdenum circuit began in October, and the circuit was operational at the end of January 2005. The mine produced about 194 t (427,000 pounds) of molybdenum in concentrate in 2005, about 80% of planned production (Platts Metals Week, 2005f).

Chile.—Chile's major copper producers, led by state-owned Corporación Nacional del Cobre (Codelco), produced 47,748 t of molybdenum in 2005, up about 14% from that of 2004. Several of Chile's copper producers have altered mine plans in order to extract ores higher in molybdenum content and have focused on molybdenum extraction over copper. Codelco's Chuquicamata Mine in northern Chile expected to produce 27,000 t of molybdenum in 2005, according to a company representative. Codelco achieved production breakthroughs in 2004 and 2005 that increased production at Chuquicamata, but that output was not sustainable. Production was expected to fall to about 20,000 t of molybdenum in 2006 (Platts Metals Week, 2005d). Molybdenum production at Antofagasta's Los Pelambres Mine was 7,900 t in 2004, down from 8,700 t in 2003, and was expected to decline further to about 7,200 t in 2005 owing to lower ore grades and reduced recoveries (Platts Metals Week, 2005c).

Santiago-based Molibdenos y Metales S.A. (Molymet) planned to invest $106 million by 2007 to increase roasting capacity by 50% at its plants in Chile and Belgium. Molymet announced that a 5,400-t/yr expansion at its FeMo converter in Chile was completed by mid-year 2005, boosting FeMo capacity there to 13,600 t/yr. An additional 3,400 t/yr of FeMo capacity planned for Molymet's FeMo plant in Belgium was likely to take place in 2006. Molymet previously announced expansion of its molybdenum concentrate roasting capacity in Chile by about 18,000 t/yr (40 million pounds) by yearend 2007, with an additional 4,500 t/yr (10 million pounds) expansion in Belgium to follow in 2009 (Ryan's Notes, 2005d).

Canadian metals producer Falconbridge Ltd. (Toronto) modified a former copper roaster at its Altonorte Smelter near Antofagasta in northern Chile to roast molybdenum concentrates. The plant began MoX production in June 2005 and achieved its design production capacity of 32 metric tons per day in less than 2 weeks. The modified plant could produce 10,000 t/yr of molybdenum oxide. Falconbridge contracted with Codelco, Chile's national copper company, to roast molybdenum concentrates from Codelco's Chuquicamata Mine (Platts Metals Week, 2005b).

China.—Molybdenum mines in the Huludao Region of northeastern China closed on government orders, and renewed safety checks were ordered in the wake of fatal coal mine accidents in February. About one-half of China's domestic supply of ferromolybdenum was lost to the market in April after authorities stopped production at about 30 companies suspected of tax fraud. The companies in northeastern Liaoning Province produced a combined 1,200 to 1,500 metric tons per month (t/mo) of FeMo (Metal Bulletin, 2005a). Mines in the Huludao region accounted for one-fourth of China's molybdenum concentrate, and about one-half of the country's FeMo exports (Metal Bulletin, 2005b). Local authorities confirmed those mining licenses that were revoked for tax fraud or illegal mining activity were to be auctioned.

Market sources said that the Chinese government had imposed a new 13% tax on molybdenum concentrate imports and a 17% tax on FeMo that is produced from imported concentrates and reexported. Export figures show that total Chinese molybdenum exports increased by more than 1,000 t/mo in June as compared with those of May and that most of the exports for June were in the form of FeMo. This pattern was the same as in 2004, when exports were low for the first 5 months and then increased sharply for several months (Ryan's Notes, 2005c).

Chinese producers stopped importing Western molybdenum concentrates by December. It was unclear if that action was because of falling MoX prices, increased consumption of domestic concentrates, or the gradual drawdown of FeMo stocks produced previously from imported concentrates. Molybdenum mines in the Huludao area of Liaoning Province were expected to remain closed until June 2006 as the Central Government worked to consolidate many small mines into larger operations that would be easier to regulate. Even if Chinese producers do not resume importing Western concentrates, the ongoing bottleneck in Western roasting capacity would continue to restrict supplies of roasted molybdenum concentrates (Ryan's Notes, 2005e).

Kazakhstan.—Eureka Mining Plc. (London, UK) expected to produce molybdenum concentrates from its Shorskoye project in early 2006, following the signing of a joint-venture agreement with KazAtomProm, the state uranium company of Kazakhstan. Under terms of the agreement, Eureka would use KazAtomProm's Stepnogorsk industrial facilities to process molybdenum concentrates from Shorskoye in exchange for a 50% interest in Ar-Man, Eureka's wholly owned subsidiary, which owns Shorskoye (Platts Metals Week, 2005e).

Outlook

Molybdenum supply continued to be constrained in 2005, even with increased concentrate production, owing to the

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continued bottleneck of insufficient Western roasting capacity. Surplus molybdenum concentrates exported to China for roasting were not reexported to the market owing to strong demand within China, coupled with reduced production from the Huludao Region owing to mine closures. Output of byproduct molybdenum was expected to rise in 2006 with the development of a 4,000-t/yr project at the Escondida Mine in Chile. In addition, the Chuquicamata Mine and the Los Pelambres Mine changed their mining plans to increase molybdenum production (Metal Bulletin Research, 2005).

Phelps Dodge expected to boost capacity at its Henderson Mine to about 18,000 t/yr (40 million pounds per year) by mid-2006 from its present capacity of about 14,500 t/yr (32 million pounds per year) (Ryan's Notes, 2005f). If Phelps Dodge Mining Company restarted its idled Climax Mine in 2008, or later, an additional 4,500 to 9,000 t/yr (10 to 20 million pounds per year) of molybdenum would probably be added to the market.

Increased production of low-cost byproduct molybdenum from South American copper mines during the next decade could adversely affect development of molybdenum deposits in North America. Because the cost of mining ore is charged against copper in a byproduct mine, byproduct molybdenum production costs are in the $1 to $2 per pound range as compared with $3 to $4 per pound for an operating molybdenum mine where molybdenum is the principal product. Many North American molybdenum deposits that would be profitable at molybdenum prices in the $6 to $8 per pound range, will probably not be developed. Increasing reliance on byproduct molybdenum could lead to greater fluctuations in molybdenum prices in the future as copper production varies according to copper market conditions.

Another factor in future molybdenum prices involves action by the Chinese Government. In an effort to restrict small-scale mining operations that do not comply with environmental or health and safety regulations, many small mines in the Huludao Region of China, which accounted for about 20% of Chinese molybdenum production in 2004, have been closed since February 2005. In addition, owing to energy shortages, environmental concerns, and government regulations, Chinese toll roasting of imported molybdenum concentrates will be restricted, further exacerbating the worldwide shortage in roasting capacity (Platts Metals Week, 2005a).

Because of abundant resources and adequate production capacity in Chile, China, the United States, and other countries, world producers expected to readily meet the future requirement for molybdenum. The principal use for molybdenum will continue to be in chemicals and catalysts and as an additive in steel manufacturing in general, most importantly alloy and stainless steel.

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TABLE 1
SALIENT MOLYBDENUM STATISTICS[1]

(Metric tons of contained molybdenum)

	2001	2002	2003	2004	2005
United States:					
Concentrate:					
Production	37,600	32,300	33,500	41,500	58,000
Shipments	37,000	32,300	33,600	42,000	57,900
Reported consumption[2]	33,300	21,200	27,500	38,700	46,600
Imports for consumption	6,010	4,710	5,190	8,780	11,900
Stocks, December 31:					
Concentrate, mine and plant	4,210	3,870	2,520	2,610	3,610
Product producers[3]	5,600	4,300	2,760	2,840	3,770
Consumers	898 r	1,800	1,900	2,040 r	2,030
Total	10,700	9,970	7,180	7,480	9,410
Primary products:					
Production	40,300	31,300	41,400	66,300	78,500
Shipments	32,600	27,500	30,100	39,300	46,700
Reported consumption	15,800	15,300	16,400	17,400	18,900
World, mine production	133,000 r	122,000 r	131,000 r	159,000 r	185,000 e

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Molybdenum concentrates roasted to make molybdenum oxide.

[3]Includes ammonium, calcium, and sodium molybdate; briquets; ferromolybdenum; molybdenum hexacarbonyl; molybdenum metal molybdenum pentachloride; molybdic acid; pellets; phosphomolybdic disulfide; and technical and purified molybdic oxide.

TABLE 2
PRODUCTION, SHIPMENTS, AND STOCKS OF MOLYBDENUM PRODUCTS IN THE UNITED STATES[1]

(Metric tons of contained Mo)

	Metal powder		Other[2]		Total	
	2004	2005	2004	2005	2004	2005
Received from other producers	--	--	15,100	17,900	15,100	17,900
Gross production during year	4,210	4,700	62,000	73,800	66,300	78,500
Molybdenum products used to make other products	3,340	3,660	38,600	45,100	42,000	48,700
Net production	868	1,050	23,400	28,700	24,300	29,800
Shipments	889	1,050	38,500	45,700	39,300	46,700
Producer stocks, December 31	172	171	2,660	3,600	2,840	3,770

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes ammonium, calcium, and sodium molybdate; ferromolybdenum; molybdenum disulfide; molybdenum hexacarbonyl; molybdenum metal; molybdenum pentachloride; molybdic acid; molybdic oxides; pellets; and phosphomolybdic acid.

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TABLE 3

U.S. REPORTED CONSUMPTION, BY END USES, AND CONSUMER STOCKS OF MOLYBDENUM MATERIALS[1]

(Kilograms of contained Mo)

End use	Molybdic oxides	Ferromolybdenum[2]	Ammonium and sodium molybdate	Molybdenum scrap	Other	Total
2004:						
Steel:						
Carbon	362,000	378,000	--	--	W	740,000
High-strength low-alloy	426,000	168,000	--	--	W	594,000
Stainless and heat-resisting	2,630,000	836,000	--	22,700	117,000	3,610,000
Full alloy	1,760,000	2,200,000	--	--	18,100	3,980,000
Tool	603,000	W	--	442	--	604,000
Total	5,790,000	3,580,000	--	23,100	135,000	9,520,000
Cast irons (gray, malleable, ductile iron)	W	920,000	--	--	27,000	947,000
Superalloys	948,000	19,500	--	(3)	1,400,000	2,360,000
Alloys (other than steels, cast irons, superalloys):						
Welding materials (structural and hard-facing)	--	68,000	--	--	733	68,700
Other alloys	W	28,000	--	913	1,050	30,000
Mill products made from metal powder[4]	--	--	--	--	1,420,000	1,420,000
Cemented carbides and related products[5]	--	--	--	--	46	46
Chemical and ceramic uses:						
Pigments	W	--	207,000	--	--	207,000
Catalysts	1,010,000	--	W	--	179,000	1,190,000
Other	--	--	--	--	14,500	14,500
Miscellaneous and unspecified uses:						
Lubricants	--	--	--	--	350,000	350,000
Other	131,000 r	89,300 r	889,000	--	187,000	1,300,000 r
Grand total	7,880,000 r	4,700,000 r	1,100,000	24,000	3,710,000	17,400,000
Stocks, December 31	464,000	656,000	16,800	17,200	880,000	2,030,000
2005:						
Steel:						
Carbon	350,000	333,000	--	--	W	683,000
High-strength low-alloy	386,000	185,000	--	--	W	571,000
Stainless and heat-resisting	1,930,000	766,000	--	33,700	78,100	2,800,000
Full alloy	1,990,000	2,590,000	--	--	18,100	4,600,000
Tool	722,000	W	--	442	--	723,000
Total	5,380,000	3,870,000	--	34,200	96,300	9,380,000
Cast irons (gray, malleable, ductile iron)	W	736,000	--	--	51,500	788,000
Superalloys	1,120,000	22,800	--	(3)	1,680,000	2,820,000
Alloys (other than steels, cast irons, superalloys):						
Welding materials (structural and hard-facing)	--	44,800	--	--	733	45,500
Other alloys	W	51,400	--	913	1,950	54,300
Mill products made from metal powder[4]	994,000	--	90,000	--	1,750,000	2,830,000
Cemented carbides and related products[5]	--	--	--	--	95	95
Chemical and ceramic uses:						
Pigments	W	--	178,000	--	--	178,000
Catalysts	1,010,000	--	W	--	179,000	1,190,000
Other	--	--	--	--	12,300	12,300
Miscellaneous and unspecified uses:						
Lubricants	--	--	--	--	279,000	279,000
Other	130,000	91,500	885,000	--	191,000	1,300,000
Grand total	8,630,000	4,820,000	1,150,000	35,100	4,240,000	18,900,000
Stocks, December 31	512,000	604,000	14,200	36,100	866,000	2,030,000

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other" of the "Miscellaneous and unspecified uses" category. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes calcium molybdate.

[3]Included with "Superalloys, other alloys."

[4]Includes construction, mining, oil and gas, and metal working machinery.

[5]Includes ingot, wire, rod, and sheet.

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TABLE 4

U.S. EXPORTS OF MOLYBDENUM PRODUCTS, BY PRODUCT AND COUNTRY[1]

Product and country	HTS[2] code	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Oxides and hydroxides, gross weight:	2825.70.0000				
Brazil		(3)	$3	--	--
Canada		2,340	23,100	3,380	$34,700
Japan		661	12,500	1,130	32,700
Mexico		3	56	13	207
Other		2,280	44,700	10,000	307,000
Total		5,280	80,300	14,600	375,000
Molybdates all, gross weight:	2841.70.0000				
Australia		14	131	6	327
Brazil		6	117	17	272
Canada		845	5,800	499	11,400
Colombia		6	41	22	581
Japan		279	2,650	146	2,830
Korea, Republic of		3	43	2	26
Mexico		370	5,240	424	8,410
Netherlands		876	13,400	843	28,400
Taiwan		6	113	4	198
Other		278	955	189	2,080
Total		2,680	28,500	2,150	54,500
Ferromolybdenum, contained weight:[4]	7202.70.0000				
Canada		870	18,700	1,930	38,500
Mexico		34	1,130	89	1,310
Netherlands		--	--	33	2,450
Other		21	1,400	34	1,140
Total		925	21,200	2,090	43,400
Molybdenum other, gross weight:[5]	Various[6]				
Australia		(3)	43	1	60
Brazil		89	3,680	92	6,840
Canada		77	2,850	127	4,690
France		42	1,770	56	5,110
Germany		100	3,970	155	13,200
Hungary		84	3,180	59	4,290
India		37	1,520	23	2,180
Italy		25	1,010	15	1,510
Japan		442	22,800	528	49,000
Mexico		13	1,270	18	1,800
Netherlands		24	1,760	25	2,250
Spain		14	717	12	1,050
Sweden		24	461	2	191
Taiwan		101	4,140	309	7,760
United Kingdom		246	7,690	399	25,100
Other		203	9,150	207	14,400
Total		1,520	66,000	2,030	139,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States.

[3]Less than ½ unit.

[4]Ferromolybdenum contains about 60% to 65% molybdenum.

[5]Includes powder, unwrought, waste and scrap, wire, wrought, and other.

[6]Includes HTS codes 8102.10.0000, 8102.94.0000, 8102.97.0000, 8102.96.0000, 8102.95.0000, and 8102.99.0000.

Source: U.S. Census Bureau.

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TABLE 5
U.S. EXPORTS OF MOLYBDENUM ORE AND CONCENTRATES
(INCLUDING ROASTED AND OTHER CONCENTRATES), BY COUNTRY[1]

	2004		2005	
Country	Quantity (metric tons of contained Mo)	Value (thousands)	Quantity (metric tons of contained Mo)	Value (thousands)
Australia	30	$322	110	$1,740
Austria	1,310	6,460	3	96
Belgium	6,470	57,900	9,430	377,000
Brazil	31	462	67	1,180
Canada	1,370	14,700	3,840	80,700
Chile	1,380	23,100	177	5,610
China	36	98	4,390	164,000
Costa Rica	27	67	4	76
Finland	638	3,990	12	801
Germany	295	1,000	136	2,310
Japan	5,730	26,000	2,050	60,200
Korea, Republic of	95	890	12	269
Mexico	3,910	26,500	3,130	34,300
Netherlands	14,100	125,000	15,000	478,000
Slovenia	815	3,610	--	--
Spain	765	3,760	5	136
Sweden	38	650	--	--
United Kingdom	8,910	61,000	7,310	224,000
Other	279	1,760	694	16,800
Total	46,200	358,000	46,400	1,450,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 6
U.S. EXPORTS OF MOLYBDENUM PRODUCTS[1]

		2004			2005		
Item	HTS[2] code	Gross weight (metric tons)	Contained Mo (metric tons)	Value (thousands)	Gross weight (metric tons)	Contained Mo (metric tons)	Value (thousands)
Molybdenum ore and concentrates, roasted	2613.10.0000	NA	33,800	$237,000	NA	26,100	$739,000
Molybdenum ore and concentrates, other	2613.90.0000	NA	12,400	121,000	NA	20,300	708,000
Molybdenum chemicals:							
Oxides and hydroxides	2825.70.0000	5,280	NA	80,300	14,600	NA	375,000
Molybdates, all	2841.70.0000	2,680	NA	28,500	2,150	NA	54,500
Ferromolybdenum	7202.70.0000	1,540	925	21,200	3,480	2090	43,400
Molybdenum powders	8102.10.0000	478	NA	18,200	612	NA	40,700
Molybdenum unwrought, bars and rods	8102.94.0000	181	NA	3,510	71	NA	4,260
Molybdenum waste and scrap	8102.97.0000	216	NA	4,330	434	NA	16,700
Molybdenum wire	8102.96.0000	177	NA	8,540	218	NA	19,600
Molybdenum, other	Various[3]	469	NA	31,400	693	NA	58,100
Total		11,000	47,100	554,000	22,200	48,500	2,060,000

NA Not available.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States.

[3]Includes HTS codes 8102.95.0000 and 8102.99.0000.

Source: U.S. Census Bureau.

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TABLE 7

U.S. IMPORTS OF MOLYBDENUM PRODUCTS, BY PRODUCT AND COUNTRY[1]

Product and country	HTS[2] code	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Oxides and hydroxides, gross weight:	2825.70.0000				
Chile		231	$6,270	773	$27,300
China		216	3,600	18	274
Germany		106	2,750	99	2,840
Russia		36	499	--	--
Uzbekistan		191	2,190	342	11,900
Other		42	511	4	150
Total		822	15,800	1,240	42,500
Molybdates all, contained weight:	Various[3]				
Belgium		--	--	2	202
Canada		2	33	6	100
Chile		850	11,400	1,060	22,400
China		425	5,770	1,480	29,000
Germany		140	2,120	93	1,090
Other		27	477	107	2,040
Total		1,440	19,800	2,750	54,800
Molybdenum orange, gross weight:	3206.20.0020				
Canada		945	4,520	702	4,040
Colombia		43	86	9	20
Korea, Republic of		--	--	(6)	3
Mexico		28	65	148	396
Other		17	89	125	321
Total		1,030	4,760	983	4,780
Ferromolybdenum, contained weight:[4]	7202.70.0000				
Belgium		12	719	32	2,240
Canada		44	1,370	382	28,600
Chile		116	3,860	313	22,300
China		4,850	148,000	3,030	214,000
Korea, Republic of		12	560	36	2,510
United Kingdom		231	2,520	114	2,390
Other		35	811	140	5,930
Total		5,310	158,000	4,050	278,000
Other, gross weight:	Various[5]				
Austria		268	14,200	312	31,100
Canada		33	852	4	180
China		265	7,250	316	22,200
Germany		32	2,580	109	8,830
Hong Kong		21	415	8	395
Japan		87	3,640	81	7,400
Korea, Republic of		(6)	8	(6)	7
Russia		90	2,600	12	1,270
United Kingdom		16	599	10	544
Other		84	2,240	28	944
Total		896	34,300	879	72,900

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States.

[3]Includes HTS codes 2841.70.1000 and 2841.70.5000.

[4]Ferromolybdenum contains about 60% to 65% molybdenum.

[5]Includes HTS codes 8102.10.0000, 8102.94.0000, 8102.95.3000, 8102.95.6000, 8102.96.0000, 8102.97.0000, and 8102.99.0000.

[6]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 8
U.S. IMPORTS OF MOLYBDENUM ORE AND CONCENTRATES (INCLUDING ROASTED AND OTHER CONCENTRATES), BY COUNTRY[1]

	2004		2005	
Country	Quantity (metric tons of contained Mo)	Value (thousands)	Quantity (metric tons of contained Mo)	Value (thousands)
Canada	2,680	$76,900	2,900	$188,000
Chile	3,570	110,000	4,930	356,000
China	18	608	47	2,850
Italy	5	38	--	--
Japan	5	38	--	--
Mexico	2,210	70,300	3,460	170,000
Netherlands	37	217	48	3,230
Other	258	9,300	475	26,200
Total	8,780	268,000	11,900	746,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF MOLYBDENUM PRODUCTS[1]

		2004			2005		
Item	HTS[2] code	Gross weight (metric tons)	Contained Mo (metric tons)	Value (thousands)	Gross weight (metric tons)	Contained Mo (metric tons)	Value (thousands)
Molybdenum ore and concentrates, roasted	2613.10.0000	7,580	4,720	$133,000	8,570	5,380	$306,000
Molybdenum ore and concentrates, other	2613.90.0000	9,330	4,070	135,000	13,800	6,480	440,000
Molybdenum chemicals:							
Oxides and hydroxides	2825.70.0000	822	NA	15,800	1,240	NA	42,500
Molybdates, all	Various[3]	2,200	1,440	19,800	4,320	2,750	54,800
Molybdenum orange	3206.20.0020	1,030	NA	4,760	983	NA	4,780
Ferromolybdenum	7202.70.0000	8,310	5,310	158,000	6,340	4,050	278,000
Molybdenum powders	8102.10.0000	139	95	4,930	93	78	7,740
Molybdenum unwrought, bars and rods	8102.94.0000	151	151	3,520	99	99	5,750
Molybdenum waste and scrap	8102.97.0000	454	415	10,200	503	480	35,600
Molybdenum wire	8102.96.0000	20	NA	2,010	21	NA	3,160
Molybdenum, other	Various[4]	132	NA	13,700	163	NA	20,700
Total		30,200	16,200	501,000	36,200	19,300	1,200,000

NA Not available.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States.

[3]Includes HTS codes 2841.70.1000 and 2841.70.5000.

[4]Includes HTS codes 8102.95.3000, 8102.95.6000, and 8102.99.0000.

Source: U.S. Census Bureau.

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TABLE 10
MOLYBDENUM-PRODUCING MINES IN THE UNITED STATES IN 2005

State and mine	County	Operator	Source of molybdenum
Arizona:			
Bagdad	Yavapai	Phelps Dodge Corp.	Copper-molybdenum ore, concentrated.
Sierrita	Pima	do.	Do.
Colorado, Henderson	Clear Creek	do.	Molybdenum ore, concentrated.
Idaho, Thompson Creek	Custer	Thompson Creek Metals Co.	Do.
Montana, Continental Pit	Silver Bow	Montana Resources	Copper-molybdenum ore, concentrated.
New Mexico:			
Chino	Grant	Phelps Dodge Corp.	Do.
Questa	Taos	Molycorp, Inc.	Molybdenum ore, concentrated.
Utah, Bingham Canyon	Salt Lake	Kennecott Utah Copper Corp.	Copper-molybdenum ore, concentrated.

TABLE 11
MOLYBDENUM: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons of contained molybdenum)

Country[3]	2001	2002	2003	2004	2005[e]
Armenia	2,943	2,884	2,763	2,950 [e]	2,750
Canada	8,233 [r]	8,043 [r]	9,090 [r]	9,520 [r]	7,910
Chile	33,492	29,466 [r]	33,374 [r]	41,883 [r]	47,748
China[e]	28,200	29,300	31,000	38,500 [r]	40,000
Iran[e]	2,400 [r]	2,300 [r]	2,200 [r]	1,800 [r]	2,000
Kazakhstan	225	230	230	230 [e]	230
Kyrgyzstan[e]	250	250	250	250	250
Mexico	5,518	3,428	3,524	3,730	4,246
Mongolia	1,514	1,590	1,793	1,141 [r]	1,188
Peru	9,499	8,613	9,561	14,246 [r]	17,325
Russia[e]	2,600	2,900	2,900	2,900	3,000
United States	37,600	32,300	33,500	41,500	58,000
Uzbekistan[e]	500	500	500	500	500
Total	133,000 [r]	122,000 [r]	131,000 [r]	159,000 [r]	185,000

[e]Estimated. [r]Revised.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 13, 2006.

[3]In addition to the countries listed, North Korea, Romania, and Turkey are believed to produce molybdenum, but output is not reported quantitatively, and available general information is inadequate to make reliable estimates of output levels.

[4]Reported figure.

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NICKEL

By Peter H. Kuck

Domestic survey data and tables were prepared by Barbara J. McNair, statistical assistant, and the world production tables were prepared by Glenn J. Wallace, international data coordinator.

Stainless steel accounted for more than 60% of primary nickel consumption in the world (Nickel Institute, 2007§[1]). However, in the United States, this percentage was only 42% because of the relatively large number of specialty metal industries and readily available stocks of scrap. Cupronickel alloys, plating, high-temperature nickel-chromium alloys, naval brasses, and superalloys and related aerospace alloys are some of the specialty uses. Nickel metal foam is increasingly being used in the manufacture of rechargeable batteries.

Largely fueled by increased use of stainless steel worldwide and strong economic growth in China, global nickel demand has grown 2% to 8% per year since 2001. World usage of stainless steel weakened during the second half of 2005 but resumed its upward movement in early 2006 (Inco Limited, 2006a, p. 22-29). Demand for nickel in batteries has grown dramatically since 1995, but still accounts for less than 5% of world nickel demand. The world nickel industry was operating close to capacity in 2005, although a few producers experienced production disruptions owing to feed material shortages, inclement weather, and labor problems.

Legislation and Government Programs

Decontamination of Radioactive Nickel Metal.—The U.S. Department of Energy (DOE) was exploring ways of recycling 13,900 metric tons (t) of radioactively contaminated nickel. The contaminated nickel was recovered during the decommissioning of uranium enrichment and related processing facilities at former nuclear defense sites. Much of the nickel is volumetrically contaminated with uranium and trace quantities of technetium-99, neptunium-237, and plutonium-239. DOE had about 8,800 t of metal ingot, typically assaying 99.96% nickel and 0.85 grams per metric ton (g/t) technetium stored at Paducah, KY. An additional 5,100 t of shredded nickel scrap was stored at Oak Ridge, TN (U.S. Department of Energy, 2007).

New U.S. Coinage.—As part of the 50 State Quarters™ Program, the U.S. Mint produced 3.01 billion commemorative quarters (25-cent coins) in 2005, up from 2.40 billion in 2004. A total of 26.72 billion of the cupronickel clad coins were minted between December 1998 and December 2005. Between 34 billion and 42 billion quarters will have been minted when the program ends in December 2008, down from previous forecasts. Since each coin weighs 5.67 grams (g) and contains 8.33% nickel, 1,423 t of nickel was used in the five commemoratives released in 2005 (U.S. Mint, 2007b§).

The U.S. Mint began releasing the golden-colored Sacagawea dollar coin in January 2000 and by yearend 2004 had struck 1.45 billion of the manganese brass-clad coins. An additional 5 million were made in 2005, excluding San Francisco proofs. The dollar coin contains 2.0% nickel and weighs 8.1 g. The U.S. Mint began modifying the Jefferson nickel (5-cent coin) in late 2003 (Public Law 108-15). There were two new designs released in 2005. Each coin weighs 5.0 g and comprises solid cupronickel with a nickel content of 25%. The Mint produced 1.74 billion of the new Jefferson nickels in 2005 (U.S. Mint, 2005§; 2007a§).

Exploration and Development.—**Alaska.**—Several companies were actively exploring for copper, nickel, and platinum-group elements (PGEs) in southeastern Alaska. Freegold Ventures Limited, Lonmin Plc (South Africa), and Pacific North West Capital Corp. were evaluating a mineralized ultramafic complex at Union Bay, 56 kilometers (km) north of Ketchikan (Freegold Ventures Limited, 2005; Pacific Northwest Capital Corp., 2005). Quattera Resources Inc. continued to evaluate several copper-nickel-PGE prospects on Duke Island, off the southwestern corner of Misty Fjords National Monument. The Duke Island complex consists of two separate, zoned ultramafic bodies—Judd Harbour and Hall Cove (Avalon Development Corporation, 2006).

Michigan.—There are no active underground metal mines operating in Michigan. However, this situation may change if the Michigan Department of Environment Quality (DEQ) recommends that the State issue a mining permit to the Kennecott Eagle Minerals Company. The proposed operation would be the only primary nickel mine in the United States.

In 2002, Kennecott Exploration (a subsidiary of London-based Rio Tinto Plc) discovered a relatively small, but high-grade copper-nickel deposit in Marquette County on the Upper Peninsula. Kennecott geologists estimated that the deposit contained 4 million metric tons (Mt) of sulfide ore grading 3.6% nickel and 3.1% copper. In April 2004, the exploration company's immediate parent, the Kennecott Minerals Company (Salt Lake City, UT) assumed responsibility for the newly named Eagle Project and launched a feasibility study (Jackman, 2005).

Minnesota.—PolyMet Mining Corp. of Vancouver, British Columbia, Canada, was seeking final regulatory approval to develop a copper-nickel-PGE deposit in northeastern Minnesota. The 250-Mt sheet-like deposit of disseminated chalcopyrite, pentlandite, and other sulfides lies on the western edge of the Duluth Complex, near the towns of Babbitt and Hoyt Lakes. The strip mine proposed by PolyMet would initially produce 25,000 metric tons per day (t/d) of ore and have a design capacity of 32,000 t/d. The ore would be shipped to the former Cliffs Erie mill near Hoyt Lakes for crushing, grinding, and subsequent flotation. In November, PolyMet purchased key parts of the mothballed taconite plant from Cleveland-Cliffs Inc and was planning to construct a state-of-the-art autoclave near

[1]References that include a section mark (§) are found in the Internet References Cited section.

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the existing concentrator. The proposed facility would produce 33,000 metric tons per year (t/yr) of copper cathode, 7,800 t/yr of nickel plus cobalt in a mixed hydroxide precipitate, and 3.73 t/yr (120,000 troy ounces per year) of contained gold and PGE in a precious metals precipitate. The NorthMet project could be operational by yearend 2008 (Murray, 2005; PolyMet Mining Corp., 2005§).

Production

Byproduct Production.—The United States did not have any active nickel mines in 2005. Except for limited quantities of byproduct nickel that were recovered at some copper and precious metal refineries, imports or recycling met all needs. In 2005, Stillwater Mining Company (majority owned by MMC Norilsk Nickel Group of Russia) shipped 685 t of nickel in crystalline sulfate (Stillwater Mining Company, 2006, p. 1-2;10-K wrap, p. 9-17). The company mines PGE ore associated with the J-M reef in Montana's Beartooth Mountains. The company's two mills (Nye and East Boulder) together processed 1.17 Mt of ore and subgrade material in 2005, with a combined mill head grade of 16 g/t of palladium and platinum. Concentrates from the two mills were being trucked to the company's smelting and refining complex at Columbus, MT, where a filter cake containing 50% to 55% PGE by weight was produced. The crystalline nickel sulfate is a refinery byproduct and contains minor amounts of cobalt.

ASARCO LLC (wholly owned by Grupo México, S.A. de C.V.) also produced limited quantities of byproduct nickel sulfate at its Amarillo copper refinery in Texas.

Limited tonnages of primary nickel are recovered during the refining of some crude oils where it occurs as porphyrins or other organometallic compounds. The nickel content of crude oil is quite variable and reflects several factors, such as density of the oil, the sulfur content of the oil, the field location, geologic occurrence, and geologic age. The nickel is concentrated in flexicoke and other petroleum refinery residues; fly ash, ash sludge, slag, and boiler scale produced at oil-fired powerplants; and spent petroleum refinery catalysts.

Secondary Production.—International Metals Reclamation Company Inc. (a subsidiary of Inco Limited) continued to produce nickel-chromium-iron remelt alloy at its metals recovery facility in Ellwood City, PA. Feed materials included chromium and nickel wastes generated by the stainless steel industry; as well as filter cakes, solutions, and sludges from the plating industry; refractory brick; spent catalysts; and spent nickel-base batteries.

Nickel can also be recovered from spent catalysts. However, extraction of nickel from catalysts is complex and has not been economic in some situations. Gulf Chemical and Metallurgical Corp. of Freeport, TX, was one of a limited number of companies worldwide that processed spent catalysts from petroleum refineries in 2005. The Freeport facility can treat nickel/molybdenum and cobalt/molybdenum hydrotreating catalysts that have been "poisoned" by nickel and vanadium in the porphyrin molecules of crude oil. Gulf Chemical converts the byproduct nickel residue to a crude nickel-cobalt alloy in an electric furnace, and then sells the alloy to nickel refineries.

Consumption

In 2005, world usage of primary nickel was reported to be 1.24 Mt, down slightly from the alltime high of 1.25 Mt reached in 2004 (International Nickel Study Group, 2006). Most nickel producers continued to operate at full capacity. Demand was buoyed by spiraling apparent consumption in China, which had risen to 198,900 t in 2005 from 43,400 t in 1999. The European Union (EU) steel industry was the leading consumer of primary nickel, followed by its counterparts in Japan and China in order of importance (Eramet Group, 2006, appendix p. 1-3).

U.S. apparent consumption of primary nickel was 136,000 t, or about 11% of world demand. U.S. industry reported consumption of an additional 77,300 t of nickel in scrap. Within the United States, the share of primary nickel consumed in the production of stainless and alloy steels decreased slightly to 46% in 2005 from 47% (revised) in 2004. The meltshop of North American Stainless (NAS) in Ghent, KY, produced 768,000 t of stainless steel slabs—11% more than that of the previous year. NAS, which started up in 2002, is a wholly owned subsidiary of Acerinox, S.A. of Madrid, Spain—the third largest stainless steel producer in the world (Acerinox, S.A., 2006, p. 95-97).

U.S. demand for most nonferrous alloys began to strengthen. Markets for copper-nickel alloys were especially hard hit in 2003, but recovered somewhat in 2004 and 2005. Consumption for superalloys—key fabrication materials for jet engines—increased by 4% compared with that of 2004. Robust sales of superalloys to the defense sector partially offset low growth in sales to civil aircraft manufacturers (Napier, 2005).

The estimated value of apparent primary nickel consumption in the United States was $2.01 billion, up from $1.77 billion in 2004—an increase of 13%. Apparent primary consumption increased by 6% from 128,000 t (revised). The increase in the value of primary consumption resulted from the combined effect of a 7% increase in the London Metal Exchange (LME) cash price and a moderate increase in primary consumption. Apparent primary consumption plus reported secondary consumption totaled 213,000 t.

Stainless Steel and Low-Alloy Steels.—In 2005, stainless steel producers accounted for 42% of primary nickel demand in the United States and more than 60% of primary demand in the world. Production of raw stainless steel (excluding production in China, Eastern Europe, and the Commonwealth of Independent States) has been increasing at a compound annual growth rate of 5.7% since 1950. Production grew to 22.08 Mt in 2004 from 14.98 Mt in 1995 (Inco Limited, 2006c, p. 4). In 2005, Western world stainless steel production declined by 5% to 20.95 Mt when stainless steelmakers realized that global production was temporarily outpacing usage despite the situation in China. This was the first year of lower output since 2001. Even with the 2005 correction, the stainless steel industry in the Western World experienced a compound annual growth rate of 3.4% for the 10-year period 1995-2005. A large part of the growth was in India, the Republic of Korea, and Taiwan, where additional melt capacity was being brought onstream to accommodate the projected growth in demand for stainless steel after 2007. There also has been a shift to increasingly larger meltshops, with seven

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stainless steel companies now having meltshops with capacities larger than 900,000 t/yr. Since 2001, China has consumed more stainless steel annually than any other country. China consumed 5.58 Mt of stainless steel in 2005, with state-owned mills producing 1.94 Mt. Chinese imports of stainless steel totaled 3.13 Mt; exports, 0.40 Mt (Inco Limited, 2006c, p. 8-9, A-37-A-38).

Production of raw stainless steel and heat-resisting steel in the United States totaled 2.24 Mt in 2005, down 7% from that of 2004, which was the highest annual production ever recorded for the United States. Nickel-bearing grades accounted for 1.41 Mt or 63% of total stainless steel production in 2005 (American Iron and Steel Institute, 2006a, p. 70-75; b).

Superalloys and Related Nickel-Base Alloys.—Of the primary nickel consumed in the United States, 17% was used to make high-performance superalloys and related nickel-base alloys for the aerospace, electric power, and petrochemical industries. U.S. production of superalloys was up 4% from that of 2004 owing to improved sales to manufacturers of jet aircraft engines and other sectors of the aerospace industry.

In August, Precision Castparts Corp. (PCC) of Portland, OR, took steps to acquire Special Metals Corporation (SMC), a leading producer of nickel-base alloys and superalloys. PCC specializes in manufacturing large, complex structural investment castings, airfoil castings, and forged components used in jet aircraft engines and industrial gas turbines. At yearend, regulatory authorities were reviewing the proposed acquisition (Precision Castparts Corp., 2005).

In September, Allegheny Technologies Inc. (ATI) announced that it was expanding its premium-melt nickel-base alloy, superalloy, and specialty alloy capabilities by about 20%. ATI was in the process of upgrading and expanding its vacuum induction melting capacity. In addition, two new electro-slag remelt furnaces and three new vacuum arc remelt furnaces were to be added to the company's operations. ATI has begun selling Allvac 718Plus, a new patented, nickel-base superalloy, to manufacturers of gas turbines (Allegheny Technologies, 2005).

Nickel-Base Batteries.—U.S. demand for nickel in rechargeable batteries continued to increase. In 2005, most of the newer hybrid electric vehicles (HEVs) on U.S. highways were using nickel-metal hydride (NiMH) batteries to store the energy recovered from the vehicle's regenerative braking circuitry—a system that reduces overall fuel consumption. Most battery manufacturers were using either pasted foam or sintered electrodes in NiMH cell production (Wasmund, 2005). The first, newer type of electrode is formed by pasting nickel hydroxide into nickel metal foam—a skeleton-like material that resembles an air filter made of aluminum.

Electric and Hybrid Electric Vehicles.—Growing HEV sales in North America increased demand for nickel foam and specialty nickel metal powders, key NiMH battery components. Since 2000, about 392,000 new HEVs have been registered in the United States. Toyota Motor Corporation has produced more than 550,000 HEVs worldwide since 1997 and was expanding capacity at its plants in Japan to 300,000 units per year (Hybrid & Electric Vehicle Progress, 2005). In the United States, sales of gasoline-electric hybrid vehicles rose sharply in 2005. Nationwide registrations of new hybrid passenger vehicles rose to 199,148 in 2005, up 139% since 2004. The U.S. market for hybrids has grown by 2,460% since its commercial debut in 2000 (R.L. Polk & Co., 2006).

Stocks

On December 31, U.S. consumer stocks of primary nickel totaled 6,640 t—16% more than the 5,750 t (revised) at yearend 2004. Stocks in LME warehouses dropped sharply during the first quarter of 2005, bottoming out at 6,024 t on April 30—the lowest level reported in more than 8 years. LME stocks, however, began building in the fall and ended the year at 36,042 t—72% more than reported at the end of 2004. Data collected by the International Nickel Study Group indicated that, at yearend 2005, world nickel producers (excluding those in Austria, China, Macedonia, Serbia, and the Ural area of Russia) had approximately 98,700 t of primary nickel stocks. About 69% or 68,400 t of the producer material was Class I materials—refined products with a nickel content of 99% or greater (electrolytic cathode, briquets, pellets, powder, rondelles, etc., in order of decreasing production). The remaining 31% was Class II materials, including ferronickel, oxide sinter, and East Asian utility nickel—products with a nickel content less than 99%. All stocks in LME warehouses are Class I (International Nickel Study Group, 2006).

Prices

The January 2005 average cash price for 99.8% pure metal on the LME was $14,501 per metric ton ($6.578 per pound)—a relatively high price in historical terms. Nickel prices strengthened during the spring, with the monthly average peaking in May, at $16,920 per ton ($7.675 per pound). Prices declined during the summer and fall and eventually recovered in December to $14,738 per ton ($6.685 per pound). The average annual price was $14,738 per ton ($6.685 per pound)—7% greater than the 2004 average.

World Industry Structure

At the beginning of 2005, the world's leading nickel producer was MMC Norilsk Nickel Group (Russia), followed by Inco (Canada). Other major producers were BHP Billiton Plc (United Kingdom), Eramet Group (France), Falconbridge Limited (Canada), and WMC Resources Ltd. (Australia). Three major developments during the year, however, triggered several acquisitions and mergers that spilled into 2006 and drastically changed corporate ownership of the nickel industry (McNish, 2006§).

BHP Billiton outbid Xstrata plc (Switzerland) for control of WMC Resources. The acquisition of WMC made BHP Billiton the third leading producer of nickel in the world, and negotiations continued into 2005. BHP Billiton named its new subsidiary Nickel West. Nickel West's nickel assets are concentrated in the State of Western Australia and include mining operations at Leinster and Mt. Keith, a concentrator at Kambalda fed by third party mines, a smelter at Kalgoorlie, and a refinery at Kwinana.

In an era of growing global nickel demand, several Chinese companies have moved to secure future supplies to meet

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expected growth in demand on the Asian mainland. Chinese companies negotiated acquisitions, joint ventures, and supply contracts with mining companies in several nickel-rich countries, including Australia, Canada, Cuba, and Papua New Guinea. In September 2004, China Minmetals Corporation offered to buy Noranda Inc., a major Canadian mining company. At the time, Noranda owned almost 59% of Falconbridge, the third leading producer of refined nickel in the world, with key operations in Canada, the Dominican Republic, and Norway. In 2005, Falconbridge produced 113,554 t of refined nickel products—9% more than the previous record high of 104,410 t set in 2003 and 9% of world supply. Minmetals was in the process of transforming itself from a trading-oriented organization into a broadly based resource company. Noranda executives eventually rejected the Chinese offer and, in a dramatic turnaround in June, agreed to be taken over by Falconbridge (Falconbridge Limited, 2005a, p. 87-89; b).

In October, Inco announced that the company was launching a friendly takeover of its long-time competitor, Falconbridge. Falconbridge's Board of Directors agreed to support Inco's takeover. The combined organization would have retained the name, Inco Limited, and would have been the leading nickel producer in the world (Falconbridge Limited and Inco Limited, 2005). At yearend, the proposed takeover was bogged down in an international antitrust review, giving Xstrata time to prepare a competing bid and eventually prevail over Inco.

While Inco was trying to acquire Falconbridge, three other metal mining companies entered the picture—Companhia Vale do Rio Doce (CVRD) S.A. de C.V. (Brazil), Phelps Dodge Corporation (United States), and Teck Cominco Limited (Canada). All three wanted to assimilate Inco into their own base-metal operations. Their entry led to even more complex negotiations in 2006 (McNish, 2006§).

World Review

Australia.—Australia was the third leading nickel-producing country in the world and was beginning to rival Canada. Most of the nickel properties under development were in Western Australia. Key events of 2005 are summarized in the nickel section of the State's Mineral and Petroleum Statistics Digest (Government of Western Australia, 2006, p. 19-20).

Laterite Operations.—Three nickel laterite mining and processing operations have been commissioned in the Kambalda-Goldfields region since 1998—Bulong, Cawse, and Murrin Murrin. Combined, the three will probably add about 60,000 t/yr of nickel to world production capacity. In 2005, Murrin Murrin, the largest of the three, produced 28,240 t of nickel, up from 27,950 t in 2004. Management efforts to resolve long-term maintenance issues will probably help boost Murrin Murrin's production in future years. Murrin Murrin is a joint venture of Minara Resources Limited (60% interest) and Glenmurrin Pty. Limited (40%), a subsidiary of Glencore International AG (Switzerland) (Minara Resources Limited, 2006, p. 7-13, 24).

In March 2004, BHP Billiton began developing its Ravensthorpe project in Western Australia and was increasing production capacity at its Yabulu nickel-cobalt refinery near Townsville, Queensland, to accommodate the output from Ravensthorpe. Inflationary pressures in Australia, material shortages, and shortages of skilled workers caused the capital cost of the integrated project to rise to $1.8 billion from the $1.4 billion originally budgeted in 2004. Of the $1.8 billion, about $1.3 billion was being used to develop the first of Ravensthorpe's three deposits and to build an onsite ore treatment facility. The remaining $460 million was being used to expand the Yabulu refinery, extending the life of the refinery by 25 years. The additional production could be available by yearend 2007. Yabulu will continue to process lateritic ores from other parts of the Asia-Pacific region. BHP Billiton has its own berth and ore handling facilities at the port of Townsville, 25 km southeast of the refinery. When the expansion is completed, Yabulu will be able to produce 76,000 t/yr of nickel and 3,500 t/yr of cobalt (BHP Billiton Plc, 2004; BHP Billiton Plc, 2006, p. 38, 93).

The Ravensthorpe minesite is about 45 km inland from Western Australia's Southern Coast and about 155 km west of the port of Esperance. Ravensthorpe had 118 Mt (dry) of proven ore reserves grading 0.75% nickel and 120 Mt (dry) of probable ore reserves grading 0.6% nickel (BHP Billiton Plc, 2006, p. 75). Ravensthorpe is designed to produce up to 220,000 t/yr of mixed nickel and cobalt hydroxide intermediate product. At yearend, much of the 55,000 cubic meters of concrete work had been completed, and the erection of some 70 chemical tanks was underway (Hellsten and Burvill, 2005).

Sulfide Operations.—Nickel West was the leading nickel producer in Western Australia. BHP Billiton created Nickel West in June to manage part of the assets acquired in the takeover of WMC. During the second half of 2005, Nickel West produced 31,700 t of nickel metal at Kwinana from concentrates smelted at Kalgoorlie. The Kalgoorlie smelter also produced 23,600 t of nickel in finished matte for export during the same 6-month period. About 45% of the concentrate came from the Mount Keith open pit mine in the Northern Goldfields region. The other 55% came from Leinster and third party mines at Kambalda. Nickel West was in the process of expanding its Mount Keith operation and was preparing to commission its new 11 Mile Well open pit (BHP Billiton, 2007, p. 14). Mount Keith had an estimated 213 Mt (dry) of proven and probable ore reserves (excluding stockpiles) averaging 0.54% nickel plus 140 Mt (dry) of additional resources averaging 0.50% nickel. Nickel West was reevaluating the undeveloped Yakabindie deposit, 25 km south of Mount Keith. Geologists estimated that the low-grade deposit had 248 Mt (dry) of indicated resources averaging 0.57% nickel (BHP Billiton Plc, 2006, p. 74-75).

Brazil.—In July, CVRD announced that it would begin developing the Vermelho nickel deposit in the Carajás region. The company's board of directors approved the expenditure of $1.2 billion for the project. Vermelho was being designed to produce 46,000 t/yr of metallic nickel and 2,800 t/yr of cobalt. A high-pressure acid leaching (HPAL) plant would be constructed onsite to extract nickel and cobalt from the lateritic ore. The proposed complex was scheduled to begin producing nickel hydroxide in the fourth quarter of 2008. Pilot-plant work has been underway in Western Australia since 2000 (Companhia Vale do Rio Doce, 2005a§). The final bankable feasibility study

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was completed in March 2005, with the original cost estimate of $900 million increased by $300 million to compensate for price increases for equipment and infrastructure (Companhia Vale do Rio Doce, 2006). The Vermelho deposit is in the State of Pará, 70 km south of the Carajás iron mines, and has 290 Mt of proven and probable reserves of limonitic laterites averaging 0.8% nickel (Companhia Vale do Rio Doce, 2005b§).

Lakefield Oretest Pty. Ltd. has been conducting HPAL studies on the Vermelho ores at its research facilities near Perth in Western Australia. A team of CVRD and Oretest engineers had extracted at least 96% of the nickel in the limonitic ore during demonstration leaching campaigns. The purified nickel solution can be used to produce LME-grade cathode (Lakefield Oretest Pty. Ltd., 2005§). The finished products would be trucked 75 km to the Carajás Railroad for transport to the Atlantic Port of Ponta da Madeira.

Canada.—Key events of 2005 are summarized in the nickel chapter of the Canadian Minerals Yearbook (Bill McCutcheon, senior commodity advisor, Natural Resources Canada, written commun., 2006-07 and unpub. data, 2006).

Manitoba and Nunavut.—Inco's operations at Thompson produced 48,500 t of finished nickel in 2005, about 8% less than the record 53,000 t reported for 2004. Declining production at Thompson from local ores was offset by imports of nickel concentrate from Australia. In August, Inco management approved $34 million to develop a lower deposit in the Thompson Mine and to improve mine productivity. The smelter at Thompson was being upgraded to better handle concentrates from the new mill at Voisey's Bay, Labrador (Inco Limited, 2006b, p. 19-25).

Newfoundland and Labrador.—In September, Inco produced its first nickel and copper concentrates at Voisey's Bay (Inco Limited, 2005; 2006c, p. 38-39). Inco began infrastructure work at the mine site in 2003 after SNC Lavalin completed a bankable feasibility study. Construction of the Ovoid open pit and the 6,000-t/d concentrator was expected to cost between $528 million and $582 million. In October, Inco commissioned its $80 million hydrometallurgical demonstration plant at Argentia, Newfoundland, but at yearend management was still evaluating potential sites for the full-scale commercial plant. Inco did not expect to complete the third and final phase of the Voisey's Bay project before 2018. In November, the Voisey's Bay operation began shipping concentrates to the Sudbury and Thompson smelters.

Ontario.—Additional reserves were being developed in Ontario's Sudbury District. Several exploration projects were also underway, particularly in and around some older, largely depleted mines. In 2005, Inco's Ontario operations mined 8.75 Mt of ore with an average grade of 1.28% nickel and 1.38% copper. The division's milling operations produced 98,000 t of nickel in concentrates in 2005, some of which was tolled (Inco Limited, 2006a, p. 1-16; 2006b, p. 25). Falconbridge Limited[2], Sudbury's other principal producer, mined 2.17 Mt of ore with an average grade of 1.16% nickel and 1.26% copper (Xstrata plc, 2007§). FNX Mining Company Inc. continued to extract ore from the reopened McCreedy West Mine and put the adjoining gold and PGE-rich PM Deposit into commercial production. In February, FNX discovered two massive copper-nickel-PGE sulfide veins in the footwall of the Levack Mine. FNX shipped 459,000 t of ore in 2005 (FNX Mining Company Inc., 2006, p. 1-7).

Falconbridge's new Montcalm Mine near Timmins mined 757,000 t of ore averaging 1.52% nickel and treated 750,000 t at the company's Kidd mill, where 9,249 t of nickel in concentrate was recovered. Montcalm has 4.1 Mt of proven and probable reserves averaging 1.38% nickel and 0.64% copper (Xstrata plc, 2007).

Quebec.—More than 20 companies are actively exploring for copper, nickel, and PGEs in the Nunavik region of northern Quebec. Much of the work has focused on the Proterozoic Cape Smith fold belt at the tip of the Ungava Peninsula. Exploration of the fold belt has accelerated since 2003 owing to high nickel prices, the continuing success of the Raglan Mine near Katinniq, and the discovery of sulfide mineralization west of Lac Chukotat. Canadian Royalties Inc., Cascadia International Resources Inc., Goldbrook Ventures Inc., Knight Resources Ltd., and Novawest Resources Inc. are just a few of the companies that have been drilling promising pyroxenite and peridotite complexes within the belt.

In 2005, the Raglan Mine, owned by Falconbridge, produced 22,917 t of nickel in concentrate, 14% less than the 26,552 t recovered in 2004. At yearend 2004, Raglan had 17.7 Mt of proven and probable reserves averaging 2.86% Ni and 0.78% Cu.

Knight Resources and its partner, Anglo American Exploration (Canada) Limited (AAEC), have been exploring a 720-square-kilometer area 90 km west of the Raglan property since 2003. Knight Resources has earned a 49% interest in the West Raglan Project operated by AAEC. The partnership has decided to refocus its attention on a 3-km by 1-km tract known as the Greater Frontier area. One particular drill hole intersected multiple mineralized zones with nickel values ranging from 0.26% to 3.37% (Knight Resources Ltd., 2005).

In 2001, Canadian Royalties optioned the Expo-Ungava property south of Raglan. By yearend 2005, Canadian Royalties had identified 11.1 Mt of indicated resources averaging 1.0% nickel and 1.2% copper in the area. The expanded program, now known as the Raglan South Nickel Project, led to the discovery of the Mesamax deposit in 2002, the Lac Mequillon deposit in 2003, and the Ivakkak deposit in late 2005. The company began constructing a 15-km-long road from the Mesamax deposit to the existing road network, providing access to the ports of Deception Bay and Douglas Harbour (Canadian Royalties Inc., 2006, p. 8-12).

China.—Chinese demand for nickel has risen dramatically since 1999. Demand for primary forms of nickel was estimated to have reached 188,500 t in 2005, 26% more than in 2004 (Eramet Group, 2006, Appendix, p. 38). Several Chinese companies have greenfield joint ventures with foreign nickel suppliers—ventures that include the Kunshun nickel chemical plant near Shanghai and a state-of-the-art nickel foam project at Dalian. In March, Jinchuan Group Limited, China's leading nickel producer, began receiving nickel matte from Nickel West's Kalgoorlie smelter under a 5-year contract signed in August 2003. The contract calls for Nickel West to export 120,000 t of nickel-in-matte to Jinchuan between 2005 and 2010 (McCutcheon, 2005, p. 23).

[2]Xstrata plc acquired Falconbridge Limited on November 1, 2006.

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The Chinese stainless steel industry currently accounts for about 46% of the country's primary nickel demand. Chinese production of stainless steel increased more than 7-fold between 1999 and 2005. Taiyuan Iron & Steel (Group) Company Ltd. (TISCO) and the Baosteel Group accounted for more than 50% of the country's stainless steel melting production (Inco Limited, 2006c, p. 4, 19-20). The country had at least eight melt shop expansions or greenfield projects underway. In April 2004, Baosteel Group commissioned a 750,000-t/yr meltshop at its No. 1 works in Shanghai, making it the largest stainless steel plant in China. China was the world's leading consumer of stainless steel in 2005, accounting for more than 25% of world stainless steel consumption.

China has a large electroplating industry and a number of rechargeable battery manufacturers that use nickel. China's plating industry accounted for about 31% of the country's primary nickel demand in 2004 (Eramet Group, 2006, Appendix, p. 38). In 2003, Inco formed a joint venture with a Chinese developer to produce nickel foam for the world market. The joint venture, Inco Wanzhong Advanced Technology Materials (Dalian) Ltd., proceeded to construct a state-of-the-art foam production plant in Dalian, a port on the Liaotung Peninsula. The Dalian plant became fully operational in 2005 and can produce 2 million square meters per year of high-quality nickel foam—the bulk of which was being sold to manufacturers of rechargeable batteries.

Cuba.—In March, Grupo Empresarial del Níquel (Cubaniquel) and its Canadian partner, Sherritt International Corporation, announced that they were planning to upgrade and expand the capacity of the Pedro Soto Alba mining and processing complex at Moa. The acid leaching operation was capable of producing 33,000 t/yr of nickel plus cobalt in a mixed sulfide precipitate and was to be increased to 49,000 t/yr. A parallel expansion was to be carried out at the joint venture's downstream refinery in Fort Saskatchewan, Alberta, Canada. In 2005, the Fort Saskatchewan refinery produced 31,878 t of nickel and 3,392 t of cobalt. About 95% of the feed came from Moa. The entire expansion project was expected to cost $450 million, with construction beginning in April 2006. The two partners were hoping to complete the first phase of the expansion by yearend 2007, increasing capacity initially by 4,000 t/yr of mixed metal. The second phase, scheduled for completion in 2009, would increase capacity an additional 9,000 t/yr (Sherritt International Corporation, 2006, p. 17-19; Granma Internacional, 2005§, 2006§).

In November 2004, China Minmetals Corporation, a parastatal enterprise, agreed to help Cuba complete construction of the long-delayed laterite-processing complex at Las Camariocas in Holguin Province. Cuban officials proposed converting the unfinished ammonia leach operation to ferronickel production, but the construction site, about 10 km southeast of Punta Gorda, has been idle for more than a decade. The adjoining mine site has at least 100 Mt of saprolitic resources averaging 1.3% nickel. Cubaniquel, the state-owned monopoly, was to have a 51% interest in the Las Camariocas project; Minmetals, a 49% interest. Las Camariocas would produce 22,500 t/yr of nickel in ferronickel. As part of the agreement, Cuba was to have supplied China with 4,000 t/yr of nickel from 2005 to 2009. Part of the new nickel production would be shipped to stainless steel plants in coastal China, with the rest going to a greenfield stainless steel plant proposed for the Guayana region of Venezuela. Minmetals was to invest $500 million in the joint venture and was considering investing an additional $1.3 billion to develop a large laterite deposit near San Felipe in Camaguey Province.

The Las Camariocas venture reportedly encountered problems in 2005, missing key project deadlines. According to the Minister of Foreign Investment and Economic Cooperation, the number of joint ventures between foreign investors and the Government of Cuba declined to 258 in December 2005 from 313 at the end of 2004 (Israel, 2007§).

Kazakhstan.—Oriel Resources plc has been evaluating the Shevchenko lateritic nickel deposits of north-central Kazakhstan. The deposits are in the Zhitigara district of Kostanai Oblast and are located in an established mining area with existing road, rail, and power networks. In December, Bateman Minerals and Metals Ltd. completed a project feasibility study with support from Mintek (South Africa), Polysius (part of the ThyssenKrupp Group, Germany), and Wardell Armstrong International Limited (WAI) (United Kingdom). The deposits, discovered in 1952, were initially estimated to have 102 Mt of resources containing 730,000 t of nickel and 51,000 t of cobalt (Oriel Resources plc, 2005a, p. 8). Confirmation drilling in 2004-05 identified proven reserves of 21 Mt averaging 0.85% nickel and probable reserves of 83 Mt averaging 0.77% nickel (Oriel Resources plc, 2005b). Three deposit areas were selected in 2004 for trial mining: Shevchenko, Blizhny, and Tarasov (Barcza and others, 2004).

In May 2004, Oriel commissioned Mintek to recommend an extraction process for the Shevchenko ores and to conduct preliminary tests on a 6-t ore sample at Mintek's direct current (DC) arc pilot plant in Randburg, South Africa. The testing was so encouraging that, a few months later, Oriel shipped a 450-t bulk ore sample to Randburg for more extensive evaluation. Mintek was able to produce ferronickel containing more than 20% nickel with a recovery rate of 89% (Mintek, 2004). Based on the Randburg evaluation, the Bateman support group recommended that Mintek's fluidized bed—DC electric furnace technology be used to produce ferronickel at Shevchenko. The smelting plant would have two 80-megawatt DC current arc furnaces. Construction, if approved, could begin in the spring of 2006; commissioning is scheduled for yearend 2008 (Oriel Resources plc, 2005a, p. 8-11; b).

New Caledonia.—In October 2004, Inco decided to restart its Goro project after simplifying the design of the hydrometallurgical processing complex. The redesign reduced construction cost estimates by $500 million. The updated capital cost estimate for the mine, processing plant, and infrastructure was $1.88 billion. Goro could begin producing cobalt and nickel by late 2007. At yearend, engineering work was about 70% complete. The plant would have a nameplate capacity of 60,000 t/yr of nickel, with ramp up to full capacity expected to take 3 years. The capacity of the redesigned plant is 9% greater than the 55,000 t/yr estimated for the previous design. Goro has exceptionally large reserves, allowing the operation to be incrementally expanded over time. Inco estimated that Goro

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had 120 Mt of proven and probable reserves averaging 1.48% nickel and 0.11% cobalt. Inco also identified 75 Mt of additional resources (Inco Limited, 2006a, p. 5, 12-16).

At yearend 2005, Inco had a 71% interest in Goro Nickel S.A.S., down from 85%. In February, the shares held by the Government of France's Bureau de Recherches Géologiques et Minières were transferred to Société de Participation Minière du Sud Calédonien S.A.S. (SPMSC)—a company owned by the three provinces of New Caledonia. SPMSC had an 8% interest in the project after yearend adjustments. In April, Sumic Nickel Netherlands B.V. [a company jointly owned by Sumitomo Metal Mining Co., Ltd. (Japan) and Mitsui & Co., Ltd. (Japan)] acquired the remaining 21% (Inco Limited, 2006a, p. 116-117).

Philippines.—On April 13, Coral Bay Nickel Corporation (CBNC) formally commissioned its $180 million hydrometallurgical processing plant near Bataraza on the island of Palawan. The plant is a joint venture of Sumitomo (54%), Mitsui (18%), Sojitz Corporation (18%), and a local Filipino company, Rio Tuba Nickel Mining Corporation (10%). The CBNC facility is designed to produce 10,000 t/yr of nickel and 700 t/yr of cobalt as a mixed sulfide precipitate. The new facility produced 4,081 t of contained nickel and about 290 t of contained cobalt in 2005. The two metals were recovered from low-grade ores stockpiled at the adjacent Rio Tuba Mine (Balitang Malacañang Office of the Press Secretary, 2005§).

Russia.—MMC Norilsk Nickel was the leading producer of nickel in the world in 2005 and accounted for about 19% of world mine production. The company's operations on the Kola and Taimyr peninsulas had a combined output of 243,000 t of nickel—about 92% of Russia's primary nickel output for the year. Almost all of the nickel was exported; only 6,000 t, or 2%, was sold to Russian consumers (MMC Norilsk Nickel Group, 2006, p. 4-6, 24-27).

The Polar Division is responsible for Norilsk Nickel's nickel mining, smelting, and refining operations on the Taimyr Peninsula of Siberia. A second division, Kola MMC, oversees similar operations on the Kola Peninsula. The PolarDivision was in the process of completing its new Skalisty Mine in the Talnakh ore field, north of the city of Norilsk. Most of the beneficiation facilities on the Taimyr Peninsula were being upgraded and/or expanded. The "Nickel Plant"—the historic sintering and smelting operation in the city of Norilsk—was to be closed and the rest of the smelting operations on the peninsula modernized. Kola MMC has begun developing the Severny-Gluboky deposit near Zapolyarny (Zapoljarnyi) on the Kola Peninsula.

At yearend 2004, proven and probable reserves on the Taimyr Peninsula totaled 318 Mt averaging 1.63% nickel and 2.79% copper, with 75% of the ore volume occurring in the Talnakh ore field. The remaining 25% was in the Norilsk-1 deposit and consisted of 80 Mt of disseminated ores averaging 0.31% nickel and 0.43% copper. The Zhdanovskoye deposit on the Kola Peninsula had 160 Mt of proven and probable reserves averaging 0.67% nickel and 0.31% copper (MMC Norilsk Nickel Group, 2006, p. 42-45, 54-58).

The remaining 8% of Russia's primary nickel output came from independent operations in the Urals region—Rezh Nickel Works JSC (Sverdlovsk Oblast), Ufaleynikel JSC (Chelyabinsk Oblast), and Yuzhuralnikel Combine JSC (Orenburg Oblast).

Amur Minerals Corporation was exploring for nickel sulfide and PGE deposits in the Russian Far East. In April 2004, ZAO Kun-Manie (a wholly owned subsidiary of Amur Minerals) was granted a license to evaluate part of the 40-km long Krumkon trend in the northeast quarter of Amur Province. The trend is close to the border with Khabarovsk Province and hosts more than 100 sills, several of which have copper-nickel mineralization. Work during the 2004 and 2005 field seasons focused on the Kun-Manie area, a 5-km long segment of the trend, about 700 km northeast of Blagoveshchensk and 750 km from the border with China. Diamond core drilling, trenching and geologic mapping helped geologists identify the Ikenskoe and Vodorazdelny target zones, and eventually four other promising zones. If the prefeasibility study is positive, the company is hoping to convert its exploration license to a 25-year mining license. The committee must submit its "Discovery Paper" to the Russian State Committee of Reserves (GKZ) before yearend 2008. The Kun-Manie license area covers some 950 square kilometers, in a region where infrastructure is minimal. Geologists estimate that the Ikenskoe and Vodorazdelny zones have indicated resources of 28 Mt of ore averaging 0.47% nickel and 0.13% copper, plus 18 Mt of inferred resources of similar grade (Amur Minerals Corporation, 2006).

Serbia.—In October, the Kosovo Trust Agency sold the ferronickel operation at Glogovac to Alferon/International Mineral Resources (Switzerland and United Kingdom) for 33 million euros (US$40 million). The trust agency has been dealing with the privatization of Kosovo's mineral assets on behalf of the United Nations Mission in Kosovo (UNMIK). Alferon is part of the Eurasian Natural Resources Group, a large privately held metals and mining conglomerate. Alferon has agreed to invest 20 million euros (US$24 million) in the mining and smelting complex before 2009, creating about 1,000 jobs in the disputed and economically depressed province. The former Feronikeli operation was badly damaged when NATO aircraft bombed Serbian forces in 1999, but the electric furnace was reported to have been relatively unscathed. Feronikeli, a socially owned enterprise of the former Socialist Federal Government of Yugoslavia, last operated in 1998. UNMIK was hoping that the privatization of Feronikeli and similar mineral-related assets would help draw international investment into the war ravaged province (Clayson, 2005§; KosovaLive News Agency, 2005§).

Spain.—In October 2004, Rio Narcea Gold Mines, Ltd. commissioned its open pit mine at Aguablanca. The new mining complex is designed to produce 8,200 t of nickel, 5,000 t of copper, and 600 kg of PGEs annually in concentrate for the next 10 years. By then, Rio Narcea expects to have its underlying underground mine fully operational. The principal ore minerals are sulfides—pentlandite, chalcopyrite, violarite and cobaltite—and occur in a conical breccia pipe (Martinez and others, 2005). The complex began commercial production in January 2005. The flotation plant can treat 1.5 Mt/yr of ore. Rio Narcea produced 5,380 t of nickel and 4,888 t of copper in concentrate during the year. At yearend, the Aguablanca open pit had 14.5 Mt of proven and probable reserves averaging 0.66% nickel, 0.46% copper, and 0.47 g/t PGE (Rio Narcea Gold Mines, Ltd., 2006, p. 7-9, 20).

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Rio Narcea planned to exploit the deposit's deeper resources within the next 4 years. Contractors finished excavating a 2.7-km-long decline to access higher grade mineralization beneath the open pit. Infill and exploratory drilling from underground and the surface continued into 2006 (Rio Narcea Gold Mines, Ltd., 2006, p. 9).

Tanzania.—In April, Barrick Gold Corporation (Toronto, Ontario, Canada) and Falconbridge announced that they had formed a joint venture to further evaluate the Kabanga nickel deposits in northwestern Tanzania. Barrick acquired the Kabanga concessions in 1999 as part of its takeover of Sutton Resources Limited. In 2005, Falconbridge acquired a 50% indirect interest in the project for $15 million and agreed to operate the joint venture. Falconbridge will fund and conduct a $50 million exploration and developmental drilling program. Barrick has significantly increased the value of Kabanga since 1999 by identifying additional resources. Three deposits have been identified to date—Main, North, and MNB. The current inferred resources total 26.4 Mt grading 2.6% nickel (Barrick Gold Corporation, 2005).

Falconbridge was prepared to fund an additional $95 million of project development to advance the Kabanga project. Project engineers have proposed an underground mining operation with an onsite surface concentrator. If the final feasibility study is successful, the proposed operation would mine 2 Mt/yr of ore and produce 30,000 to 35,000 t/yr of nickel in sulfide concentrates.

Turkey.—European Nickel PLC (ENickel) (London, United Kingdom) has been evaluating the Caldag laterite deposit since 2002. The Caldag deposit is 15 km north of the town of Turgutlu and 75 km northeast of the Port of Izmir. In July 2004, the Government of Turkey issued an environmental license to the company, allowing it to begin trial heap leaching. ENickel has since shown that acid heap leaching can be used to economically recover nickel from laterites with low clay contents, like those in the Balkans and Turkey. Equatorial laterites, in contrast, have significantly higher clay contents and are less amenable to the ENickel process. The cobalt and nickel were being recovered as a mixed hydroxide (European Nickel PLC, 2006a, p. 4-5; b).

A feasibility study was launched in October 2004 and completed in November 2005. The bankable feasibility study allowed the company to seek full funding of the project and move forward to the detailed design phase. Aker Kvaerner Australia Pty. Limited was selected for front-end engineering and design. Three trial leach pads and a precipitation plant were built onsite as part of the feasibility study to demonstrate the viability of the ENickel process. More than 70% of the nickel contained in the heap was recovered. The trial precipitation plant has produced mixed hydroxide on a near continuous basis since May 2005. ENickel completed a 31,000-meter drilling program at Caldag. Analysis of the drill data by independent resource consultants, using a 0.6% nickel cutoff, indicated that the deposit had 23.1 Mt of proven reserves grading 1.32% nickel and 0.07% cobalt. The deposit also had 12.9 Mt of "provable" [sic] reserves grading 1.27% nickel and 0.07% cobalt (European Nickel PLC, 2006a, p. 5).

Development of the $300 million project was scheduled to start in September 2006, with full-scale production of hydroxide to begin in late 2008. The design capacity of the project was recently raised. The operation is now expected to produce 20,400 t/yr of nickel and 1,200 t/yr of cobalt as mixed hydroxide. Limited mining had been underway since 2003, when 40,000 t of ore was shipped to ferronickel smelters in Greece and Macedonia (European Nickel PLC, 2006b).

ENickel hoped to adapt the technology developed at Caldag to similar deposits in Albania and Serbia. The company had obtained licenses from the Government of Serbia to evaluate the Lipovac and Mokra Gora deposits in the central part of that country. ENickel continued to collect geological information on Lipovac, but returned its Mokra Gora license to the Serbian Government after the Mokra Gora area became part of a national park (European Nickel PLC, 2006a, p. 8-9). At yearend, BHP Billiton had an 8% interest in ENickel. The two companies have been discussing ways of improving collaboration on the Caldag project and the jointly developed heap-leach process.

Zimbabwe.—Bindura Nickel Corporation operated two underground mines during 2005—Shangani and Trojan. Geologists estimate that the Shangani Mine has only 2 years of reserves remaining and were trying to determine how best to extend the existing shaft system to reach additional resources. The Trojan Mine has an estimated 7 years of reserves. The Trojan shaft was being deepened by some 600 meters to access new reserves that could extend the life of the mine to the year 2024. The company was also conducting a feasibility study of the Hunters Road deposit.

Nickel sulfide concentrates from Shangani and Trojan are processed in the smelter and refinery at the town of Bindura. In 2005, the refinery produced 11,000 t of nickel cathode. About 7,000 t was recovered from Shangani and Trojan concentrates; the remaining 4,000 t came from toll material shipped from Botswana and South Africa. Mwana Africa plc has a 52.9% interest in Bindura. Mwana acquired the controlling stake from Anglo American Corporation of Zimbabwe in July 2003 (Mwana Africa plc, 2006§).

Current Research and Technology

Growing demand for rechargeable NiMH batteries has encouraged researchers to reevaluate existing processes for recovering nickel from spent batteries. Spent NiMH batteries typically contain 36% to 42% nickel, 3% to 4% cobalt, and 8% to 10% mischmetal (consisting largely of lanthanum, cerium, praseodymium and neodymium). The cathode of the battery is made of nickel metal coated with nickel hydroxide, while the anode consists of a hydrogen storage alloy made from cobalt, mischmetal, and nickel. The bulk of the nickel currently recovered from spent NiMH and nickel-cadmium batteries ends up in an iron-chromium remelt alloy, which is then sold to stainless steel producers as a relatively inexpensive source of chromium and nickel. In this process, the cobalt follows the nickel while the rare earths are lost to the slag. Researchers at Aachen University in Germany recently published their study of the rare earth recovery problem. They propose using a calcium oxide-calcium fluoride slag system to recover the rare earths as oxides, making NiMH battery recycling more profitable. A centralized dedicated battery recycling plant could make

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economic sense for highly industrialized regions such the EU, Japan, and the United States where recycling systems already exist. An estimated 10,000 t of NiMH batteries was sold in the EU in 2003 (Müller and Friedrich, 2006).

Outlook

No primary nickel producer is expected to be operating in the United States before 2015, with the possible exception of Kennecott's proposed underground mine in the Upper Peninsula of Michigan. Grupo México and Stillwater will continue to recover limited amounts of byproduct nickel from precious metals and base-metals refining operations in the western United States. Larger amounts of byproduct nickel could also be generated in Minnesota if PolyMet or Teck Cominco Limited decide to proceed with their PGE projects in the Duluth Gabbro. Increased byproduct nickel production from North American PGE operations could materialize if current forecasts for fuel cell-battery hybrid vehicles are accurate.

U.S. nickel consumers will apparently be dependent on foreign sources for at least two decades. The ongoing expansion of nickel laterite mining operations in Australia, Cuba, Indonesia, New Caledonia, and the Philippines will help meet the growing demand for nickel worldwide. Laterite projects are also under consideration in Brazil, Cote d'Ivoire, Guatemala, and Kazakhstan. The sulfide concentrate from Inco's state-of-the-art mill and concentrator at Voisey's Bay will also help meet the near-term growth in demand projected for nickel. The world consolidation of nickel operations is expected to continue.

Rising prices for petroleum products have increased demand for hybrid automobiles and with it, NiMH batteries. In the United States, hybrid vehicles were in short supply, reportedly because of the limited availability of NiMH battery packs and the large financial costs associated with scaling-up production. The life and replacement cost of the different NiMH battery packs remain important issues (Williams, 2006§).

Between 1997 and yearend 2005, Toyota Motor Corporation of Tokyo, Japan, sold more than 550,000 hybrid vehicles worldwide. The second-generation hybrids currently being manufactured by Toyota perform better and are less costly to manufacture than the original 1997 Prius. The company is now planning to produce more than 1 million hybrid vehicles annually by 2012 (Toyota Motor Corporation, 2006, p. 11).

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TABLE 1
SALIENT NICKEL STATISTICS[1]

(Metric tons of contained nickel unless otherwise specified)

	2001	2002	2003	2004	2005
United States:					
Mine production	--	--	--	--	--
Plant production	--	--	--	--	--
Secondary recovery from purchased scrap:					
From ferrous scrap	69,300	74,900	74,000	73,500	68,900
From nonferrous scrap	11,900	9,060	9,510	9,790	8,380
Shipments of purchased scrap[2]	121,000	114,000	119,000	113,000	117,000
Exports:					
Primary	8,450	6,520	6,330	8,000	7,630
Secondary	48,600	39,400	47,300	48,300	55,600
Imports for consumption:					
Ore	--	--	--	--	--
Primary	136,000	121,000	125,000	136,000	143,000
Secondary	8,760	9,110	11,500	18,800	15,500
Consumption:					
Reported:					
Primary	98,800	88,200	87,300 r	98,900 r	96,800
Secondary, purchased scrap[3]	81,200	83,900	83,500	83,300	77,300
Total	180,000	172,000	171,000	182,000	174,000
Apparent:					
Primary	129,000	121,000	117,000	128,000	136,000
Secondary, purchased scrap[4]	41,800	54,600	48,400	54,900	37,600
Total	171,000	175,000	165,000	183,000 r	174,000
Apparent primary plus reported secondary	210,000	205,000	200,000	212,000	213,000
Stocks, yearend:					
Government	--	--	--	--	--
Producers and traders	12,600	6,150	8,040	6,580	4,960
Consumer, primary	4,500	4,520	4,800	5,750 r	6,640
Consumer, secondary	7,980	7,040	6,270	5,210	4,860
Total	25,100	17,700	19,100	17,500 r	16,500
Employment, yearend:					
Mine	--	--	--	--	--
Smelter	--	--	--	--	--
Port facility	--	--	--	--	--
Price, cash, London Metal Exchange:					
Average annual dollars per metric ton	5,945	6,772	9,629	13,823	14,738
Average annual dollars per pound	2.696	3.072	4.368	6.270	6.685
Price, 18/8 stainless steel scrap, gross weight:[5]					
Average annual dollars per metric ton	623	692	927	1,450	1,450
Average annual dollars per long ton	633	703	942	1,470	1,470
World, mine production	1,350,000 r	1,350,000	1,370,000 r	1,400,000 r	1,480,000 e

eEstimated. rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; except prices; may not add to totals shown.

[2]Defined as scrap receipts less shipments by consumers plus exports minus imports plus adjustments for consumer stock changes.

[3]More clearly delineates the amount consumed than does apparent consumption.

[4]Internal evaluation indicates that apparent secondary consumption is considerably understated.

[5]Derived from the average of the Friday consumer buying price range for 18% chromium—8% nickel scrap in bundles, solids, and clips, Pittsburgh, PA, in American Metal Market.

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TABLE 2
NICKEL RECOVERED FROM PURCHASED SCRAP IN THE UNITED STATES, BY KIND OF SCRAP AND FORM OF RECOVERY[1]

(Metric tons of contained nickel)

	2004	2005
Kind of scrap:		
Aluminum-base[2]	2,960	2,410
Copper-base	2,590 r	2,290
Ferrous-base[3]	73,500	68,900
Nickel-base	4,230 r	3,680
Total	83,300	77,300
Form of recovery:		
Aluminum-base alloys	2,960	2,410
Copper-base alloys	4,080 r	3,630
Ferrous alloys	73,500	68,900
Nickel-base alloys	2,690 r	2,340
Miscellaneous and unspecified	48 r	--
Total	83,300	77,300

rRevised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Primarily borings and turnings of wrought alloys, such as 2218, 2618, 4032, and 8280, or special casting alloys, such as 203.0.
[3]Primarily stainless and alloy steel scrap consumed at steel mills and foundries.

TABLE 3
REPORTED U.S. CONSUMPTION OF NICKEL, BY FORM[1]

(Metric tons of contained nickel)

Form	2004	2005
Primary:		
Metal	78,100 r	81,700
Ferronickel	13,800 r	13,300
Oxide and oxide sinter[2]	187 r	164
Chemicals	5,860	981
Other	1,010	639
Total	98,900 r	96,800
Secondary, scrap[3]	83,300	77,300
Grand total	182,000	174,000

rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes chemical-grade oxide.
[3]Based on gross weight of purchased scrap consumed and estimated average nickel content.

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TABLE 4
U.S. CONSUMPTION OF NICKEL, BY USE[1]

(Metric tons of contained nickel)

Use	2005								Grand total in 2004
	Metal	Ferronickel	Oxide and oxide sinter	Chemicals	Other forms	Total primary	Secondary (scrap)	Grand total	
Consumption reported:									
Cast irons	51	W	W	--	W	51	128	179	306 r
Chemicals and chemical uses	1,350	--	W	678	--	2,030	W	2,030	6,270 r
Electric, magnet, expansion alloys	161	--	--	--	--	161	W	161	192
Electroplating, sales to platers	11,200	--	--	128	--	11,300	--	11,300	11,900
Nickel-copper and copper-nickel alloys	2,910	--	W	--	15	2,930	2,930	5,860	5,990 r
Other nickel and nickel alloys	15,000	W	W	--	61	15,000	2,200	17,200	15,400
Steel:									
Stainless and heat resistant	27,700	13,200	68	W	200	41,200	67,500	109,000	115,000 r
Alloys, excludes stainless	3,430	W	--	--	W	3,430	593	4,020	3,770
Superalloys	15,900	--	W	W	251	16,100	139	16,300	15,700 r
Other[2]	4,150	117	96	175	112	4,650	3,790	8,430	7,800 r
Total	81,700	13,300	164	981	639	96,800	77,300	174,000	182,000
Consumption, apparent	XX	XX	XX	XX	XX	136,000	37,600	174,000	183,000

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes batteries, catalysts, ceramics, coinage, other alloys containing nickel, and data indicated by the symbol "W."

TABLE 5
NICKEL IN CONSUMER STOCKS IN THE UNITED STATES, BY FORM, DECEMBER 31[1]

(Metric tons of contained nickel)

Form	2004	2005
Primary:		
Metal	4,060 r	4,780
Ferronickel	909 r	944
Oxide and oxide sinter	58 r	68
Chemicals	570	778
Other	150	69
Total	5,750 r	6,640
Secondary, scrap	5,210	4,860
Grand total	11,000 r	11,500

rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 6
U.S. EXPORTS OF NICKEL PRODUCTS, BY CLASS[1, 2]

Class	2004 Quantity (metric tons, contained Ni)	2004 Value (thousands)	2005 Quantity (metric tons, contained Ni)	2005 Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	972	$10,900	1,190	$17,600
Ferronickel	68	466	72	520
Powder and flakes	2,130	34,800	1,910	33,900
Metallurgical-grade oxide	201	2,140	233	2,120
Chemicals:				
Catalysts	1,980	104,000	2,150	134,000
Salts[3]	2,650	34,500	2,070	30,200
Total	8,000	186,000	7,630	219,000
Secondary:				
Stainless steel scrap	35,900	548,000	43,800	670,000
Waste and scrap	12,400	60,800	11,700	60,000
Total	48,300	609,000	55,600	731,000
Grand total	56,300	795,000	63,200	949,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	302	3,880	215	4,030
Sheets, strip, foil	579	10,900	786	19,700
Tubes and pipes	234	1,590	335	3,030
Total	1,120	16,400	1,340	26,700
Alloyed, gross weight:				
Unwrought alloyed ingot	7,510	80,600	10,400	99,900
Bars, rods, profiles, wire	12,300	224,000	16,400	374,000
Sheets, strip, foil	4,720	92,900	4,320	118,000
Tubes and pipes	1,800	50,700	3,000	81,200
Other alloyed articles	3,440	118,000	3,580	147,000
Total	29,700	566,000	37,700	819,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]The nickel contents are as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The salts category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; and sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel.
[3]Excludes nickel carbonate (more information can be found in the Harmonized Tariff System Schedule B, export commodity code 2836.99.9050).

Source: U.S. Census Bureau.

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TABLE 7
U.S. EXPORTS OF NICKEL PRODUCTS, BY COUNTRY[1]

(Metric tons, contained Ni)[2]

	2005									
Country	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferronickel	Metallurgical-grade oxide[3]	Waste and scrap	Stainless steel scrap	Chemicals	Total	Total in 2004	Wrought nickel in 2005[4]
Australia	--	10	--	(5)	500	6	21	537	123	36
Belgium	17	39	--	--	19	53	126	254	256	(5)
Brazil	20	16	--	--	--	7	9	52	167	13
Canada	124	467	10	77	8,990	1,790	1,190	12,700	13,900 r	96
China	--	143	7	2	157	18,100	190	18,600	12,400	180
Colombia	2	10	--	--	--	(5)	5	17	123	254
Finland	--	38	--	--	113	4,830	229	5,210	5,670 r	--
France	--	111	--	--	12	11	18	152	170	40
Germany	(5)	199	1	113	339	79	37	768	848	30
India	--	9	--	--	30	2,560	102	2,700	1,940	8
Italy	--	35	--	(5)	--	1,370	45	1,450	85	21
Japan	16	87	7	14	246	451	372	1,190	1,100	132
Korea, Republic of	--	57	--	--	--	3,740	228	4,020	7,000	130
Mexico	986	121	--	1	1	2,320	196	3,620	1,240	58
Netherlands	--	16	--	--	69	874	82	1,040	1,260	8
South Africa	--	10	--	--	19	--	62	91	72	16
Spain	(5)	24	--	--	--	771	--	795	696	(5)
Sweden	--	(5)	--	--	347	4	57	408	351	4
Taiwan	7	47	--	1	41	5,280	86	5,470	3,400	23
United Kingdom	1	125	37	18	695	221	133	1,230	1,270	31
Other	18	345	10	7	162	1,350	1,040	2,930	4,150 r	256
Total	1,190	1,910	72	233	11,700	43,800	4,230	63,200	56,300	1,340

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]The nickel contents are assumed to be as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The chemicals category contains the following: chemical-grade oxide, sesquoxide, and hydroxide, 65%; chlorides, 25%; and sulfate, 22%. Other salts and various catalysts are assumed to be 22% nickel.

[3]Chemical-grade oxide is included in the "Chemicals" category.

[4]Excluded from "2005, total."

[5]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY CLASS[1]

Class	2004 Quantity (metric tons, contained Ni)[2]	2004 Value (thousands)	2005 Quantity (metric tons, contained Ni)[2]	2005 Value (thousands)
Primary:				
Unwrought:				
Cathodes, pellets, briquets, shot	107,000	$1,450,000	110,000	$1,620,000
Ferronickel	13,900	168,000	19,200	185,000
Powder and flakes	9,220	140,000	8,120	128,000
Metallurgical-grade oxide	1,210	17,500	1,540	24,500
Chemicals:				
Catalysts	1,310	68,800	1,220	70,800
Salts[3]	3,130	45,700	2,410	39,100
Total	136,000	1,890,000	143,000	2,060,000
Secondary:				
Stainless steel scrap	11,000	160,000	8,340	124,000
Waste and scrap	7,850	89,700	7,170	99,200
Total	18,800	250,000	15,500	223,000
Grand total	155,000	2,140,000	159,000	2,290,000
Wrought, not alloyed:				
Bars, rods, profiles, wire	499	9,740	534	12,200
Sheets, strip, foil	260	9,220	419	11,100
Tubes and pipes	38	1,350	104	2,670
Total	797	20,300	1,060	26,000
Alloyed, gross weight:				
Unwrought alloyed ingot	3,000	37,400	4,840	74,700
Bars, rods, profiles, wire	8,860	137,000	10,300	209,000
Sheets, strip, foil	2,920	58,600	3,490	83,700
Tubes and pipes	3,060	52,100	1,850	38,400
Other alloyed articles	2,080	63,600	2,800	75,500
Total	19,900	349,000	23,300	481,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]The nickel contents are as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The salts category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%; and other salts which are assumed to be 22% nickel. The typical catalyst is assumed to have a nickel content of 22%. Waste and scrap is assumed to be 50% nickel; stainless steel scrap, 7.5% nickel.
[3]Excludes nickel carbonate (more information can be found at Harmonized Tariff Schedule of the United States subheading 2836.99.5000).

Source: U.S. Census Bureau.

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TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY COUNTRY[1]

(Metric tons of contained nickel)[2]

	2005									
Country	Cathodes, pellets, and briquets (unwrought)	Powder and flakes	Ferronickel	Metallurgical-grade oxide[3]	Waste and scrap	Stainless steel scrap	Chemicals	Total	Total in 2004	Wrought nickel in 2005[4]
Australia	11,700	419	--	--	28	--	--	12,100	11,400	10
Austria	--	1	--	--	--	--	--	1	5	138
Belgium	4	76	--	--	14	5	326	426	358	--
Brazil	1,410	(5)	--	--	36	1	--	1,450	2,080	--
Canada	51,800	4,420	--	1,520	2,080	5,490	25	65,400	69,600	3
China	380	23	--	--	74	108	26	611	77	21
Colombia	--	--	3,670	--	--	52	--	3,730	3,280	--
Dominican Republic	--	41	13,800	--	--	33	--	13,800	8,710	--
Finland	1,910	869	--	--	10	3	1,130	3,920	6,490	--
France	792	--	--	--	1,230	25	273	2,320	2,420	183
Germany	1	47	--	--	416	(5)	455	919	2,040	498
Japan	--	50	--	1	187	8	357	603	854	64
Mexico	--	--	--	--	247	2,340	24	2,610	2,200	(5)
Netherlands[6]	228	--	3	--	77	--	579	887	914	(5)
New Caledonia	--	--	1,500	--	--	--	--	1,500	1,360	--
Norway	19,400	--	--	--	29	3	--	19,400	14,800	4
Russia	20,900	1,050	321	--	25	--	--	22,200	20,100	--
South Africa	112	557	--	--	--	--	--	669	817	--
United Kingdom	341	538	1	15	1,730	9	131	2,770	3,670	83
Venezuela	--	--	--	--	174	77	--	252	443	--
Zimbabwe	1,550	--	--	--	--	--	--	1,550	941	--
Other	24	28	--	4	813	190	296	1,360	2,170	53
Total	110,000	8,120	19,200	1,540	7,170	8,340	3,630	159,000	155,000	1,060

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]The nickel contents are assumed to be as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The chemicals category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel. Waste and scrap is assumed to be 50% nickel, and stainless steel scrap, 7.5% nickel.

[3]Primarily oxide, rondelles, and sinster.

[4]Excluded from "2005, total."

[5]Less than ½ unit.

[6]The different nickel products (cathode, powder, etc.) are apparently materials that have transited through bonded warehouses in the Netherlands, including warehouses overseen by the London Metal Exchange.

Source: U.S. Census Bureau.

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TABLE 10
NICKEL: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons of contained nickel)

Country	2001	2002	2003	2004	2005[e]
Australia, content of concentrate	205,000	207,800	210,000	178,100	189,000 [3]
Botswana, content of ore milled	26,714	28,600	32,740	32,980	28,000
Brazil, content of ore	45,456	44,928	45,160	45,200 [e]	52,000 [p, 3]
Burma, content of ore[e]	10 [r]	10 [r]	10 [r]	10 [r]	10
Canada, content of concentrate	194,058	189,297	163,244	186,694 [r]	198,369 [p, 3]
China[e]	51,500	53,700	61,000	75,600 [r]	77,000
Colombia, content of laterite ore	52,962	58,196	70,844	75,032	89,031 [3]
Cuba, content of oxide, oxide sinter, oxide powder, sulfide, ammoniacal liquor[4]	72,585	71,355 [r]	67,306 [r]	71,933 [r]	72,000
Dominican Republic, content of laterite ore	39,120	38,859	45,253 [r]	46,000 [r]	46,000
Finland, content of concentrate[5]	2,600 [r]	3,120 [r]	3,640 [r]	3,700 [r]	3,400
Greece, content of laterite ore	20,830	22,670	21,410	21,700	23,210 [3]
Indonesia, content of laterite ore	102,000	123,000	143,000	133,000	160,000
Kazakhstan, content of laterite ore	--	--	--	--	193 [3]
Macedonia, content of ferronickel produced	2,970 [e]	5,149	5,555	5,300 [r]	8,100 [3]
Morocco, content of nickel sulfate	151	109	126	130 [r]	130
New Caledonia, content of ore	117,734	99,841	112,013	118,279	111,900 [3]
Norway, content of concentrate[6]	2,529	2,052	169	181	150
Philippines:					
Content of ore	27,359	26,532	19,537	16,973	22,555 [p, 3]
Content of concentrate[7]	--	--	--	--	4,081 [p, 3]
Russia, content of ore[e]	320,000	310,000 [r]	300,000 [r]	315,000	315,000
South Africa, content of concentrate	36,443	38,546	40,842	39,853 [r]	42,497 [p, 3]
Spain, content of concentrate	--	--	--	(8)	5,398 [3]
Turkey, content of laterite ore[9]	--	--	640	40 [r, e]	1,000
Ukraine, content of laterite ore[e]	1,500	2,000	2,000	2,000	2,000
Venezuela, content of laterite ore	13,600	18,600	20,700	20,468	20,000
Zimbabwe, content of concentrate	10,120	8,092	9,517	9,520	9,500
Grand total	1,350,000 [r]	1,350,000	1,370,000 [r]	1,400,000 [r]	1,480,000
Of which:					
Content of concentrate	451,000 [r]	449,000 [r]	427,000 [r]	418,000 [r]	452,000
Content of ore and ore milled	537,000	510,000 [r]	509,000 [r]	528,000	529,000
Content of laterite ore	230,000	263,000	304,000	298,000 [r]	341,000
Content of ferronickel produced	2,970	5,150	5,560	5,300 [r]	8,100
Content of nickel sulfate	151	109	126	130 [r]	130
Content, unspecified and/or undifferentiated	124,000	125,000	128,000 [r]	148,000 [r]	149,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Insofar as possible, this table represents recoverable mine production of nickel. Where actual mine output is not available, data related to a more highly processed form have been used to provide an indication of the magnitude of mine output and this is noted parenthetically. North Korea may have an active nickel mine, but information is inadequate to make reliable estimates of output. Table includes data available through August 3, 2006.

[3]Reported figure.

[4]The Government of Cuba reports plant production on a contained nickel plus cobalt basis. The tonnages shown in this table for Cuba have been adjusted downward to correct for the cobalt. The cobalt content was determined to be 1.16% for granular and powdered oxide, 1.21% for oxide sinter, 7.56% for sulfide precipitate, and 33% for leach ammoniacal precipitate.

[5]The gross weight of concentrates processed in Finland from domestic ores was, as follows, in metric tons: 2001—27,610; 2002—47,797; 2003—41,289; 2004—45,914; and 2005—39,854.

[6]A/S Nikkel Og Olivin halted mining operations in October 2002. Outokumpu Oyj sold its 70% interest in the Norwegian mining company to Boliden AB on December 30, 2003.

[7]Nickel content of concentrate produced at Rio Tuba in 2005 by Coral Bay Nickel Corp.

[8]The Aguablanca operation of Rio Narcea Gold Mines, Ltd. was commissioned in December 2004.

[9]European Nickel PLC began large scale heap–leaching trials at its Caldag laterite operation in October 2004.

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TABLE 11
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT[1, 2]

(Metric tons of contained nickel)

Country and product[3]	2001	2002	2003	2004	2005
Australia:					
Metal	116,900	120,800	115,800	111,500 r	113,000 p
Unspecified[4]	11,200	11,400	13,600	10,700 r	9,000 p
Total	128,100	132,200	129,400	122,200 r	122,000 p
Austria, ferronickel[e]	1,600	1,500	1,500	1,500	1,500
Brazil:[5]					
Ferronickel	5,768	6,011	6,409	6,493 r	6,500 p
Metal	17,663	17,676	18,155	19,742 r	19,750 p
Total	23,431	23,687	24,564	26,235 r	26,250 p
Canada, unspecified[6]	140,591	144,476	124,418	151,518	139,683 p
China, metal[e]	49,700	52,400	64,700	75,800 r	95,000
Colombia, ferronickel	38,438	43,987	47,868	48,818 r	52,749
Cuba, oxide sinter and oxides[7]	40,750 r	38,751 r	35,605 r	38,231 r	38,200 e
Dominican Republic, ferronickel	21,661	23,303	27,227	29,477	28,668 p
Finland:					
Metal	51,275	49,151	45,417 r	40,088 r	40,000 e
Chemicals	3,700	3,600	3,600	3,500	3,500 e
Total	54,975	52,751	49,017 r	43,588 r	43,500 e
France:					
Metal	11,033	9,444	9,138	10,103	10,684
Chemicals[e]	2,000 [8]	2,000	2,000	2,000	2,000
Total[9]	13,033	11,444	11,138	12,103	12,684 p
Greece, ferronickel	16,870	19,229	18,000	18,115	19,235 p
Indonesia, ferronickel	10,302	8,804	8,933	7,945	7,338
Japan:					
Ferronickel	68,113	74,418	75,399	74,261	77,600 e
Metal	32,526	32,303 r	34,991	32,769 r	29,399
Oxide sinter	50,771	48,950	52,663 r	60,285 r	58,100 e
Chemicals	2,394	1,820	2,084	2,082	2,208
Total	153,804	157,491 r	165,137 r	169,397 r	167,307
Korea, Republic of, metal	(10)	(10)	(10)	(10)	(10)
Macedonia, ferronickel	2,970 e	5,149	5,555	5,300 r	8,100
Morocco, chemicals	151	109	126	130 r	130 e
New Caledonia, ferronickel	45,912	48,650	50,666	43,016	46,738 p
Norway, metal	68,221	68,530	77,183	71,410	84,886 p
Poland, chemicals[11]	704	744	785	820	800
Russia:[e]					
Ferronickel	8,000	12,000	13,500	14,000	13,000
Metal	252,000 r	239,000 r	260,000 r	261,000 r	266,000
Oxide sinter	12,000	6,000	5,000	5,000	5,000
Chemicals	2,000	2,000	2,500	3,000	3,000
Total	274,000 r	259,000 r	281,000 r	283,000 r	287,000
South Africa:					
Metal	30,500	31,646	25,500 e	32,680	35,000
Chemicals[12]	5,943	6,900	15,342	7,170 e	7,500
Total	36,443	38,546	40,842	39,850	42,500
Taiwan, metal	(10)	(10)	(10)	(10)	(10)
Ukraine, ferronickel[e, 13]	2,500	6,000	-- r	12,000 r	14,000
United Kingdom, metal	33,817	33,790	26,788	38,606	37,127 p
Venezuela, ferronickel	9,700	15,500	17,200	17,400	16,900 p
Zimbabwe, metal:					
Refined from domestic materials[14]	7,440	8,092	9,517	9,520	9,500 e
Toll refined from imported materials[15]	12,084	10,812	3,140	2,500 e	2,500
Total	19,524	18,904	12,657	12,020	12,000 e

See footnotes at end of table.

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TABLE 11—Continued
NICKEL: WORLD PLANT PRODUCTION, BY COUNTRY AND PRODUCT[1, 2]

(Metric tons of contained nickel)

Country and product[3]	2001	2002	2003	2004	2005
Grand total	1,190,000 r	1,200,000 r	1,220,000	1,270,000 r	1,300,000
Of which:					
Ferronickel	232,000	265,000	272,000 r	278,000 r	292,000
Metal	683,000 r	674,000 r	690,000 r	706,000 r	743,000
Oxide sinter	104,000 r	93,700	93,300 r	104,000 r	101,000
Chemicals	16,900	17,200	26,400	18,700	19,100
Unspecified	152,000	156,000	138,000	162,000 r	149,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through August 3, 2006.

[3]In addition to the countries listed, North Korea is believed to have produced metallic nickel and/or ferronickel, but information is inadequate to make reliable estimates of output levels. Several countries produce nickel-containing matte, but output of nickel in such materials has been excluded from this table to avoid double counting. Countries producing matte for export are listed in table 12.

[4]Class II products with a nickel content of less than 99%. Includes oxides and oxide sinter. Excludes intermediate nickel-cobalt sulfide matte, regulus, and speiss for further refining.

[5]Brazil produced nickel carbonate (an intermediate product), in metric tons: 2001—17,063; 2002—18,100; 2003—18,406; 2004—19,897 (revised); and 2005–19,900 (preliminary).

[6]Nickel contained in products of smelters and refineries in forms, which are ready for use by consumers. Figures include the nickel content of nickel oxide sinter exported to the Republic of Korea and Taiwan. More information can be found in footnote 9.

[7]Cuba also produces nickel sulfide, but because it is used as feed material elsewhere, it is not included to avoid double counting. Combined output of processed sulfide and ammoniacal liquor precipitate was, as follows, in metric tons of contained nickel: 2001—31,884; 2002—28,548; 2003—31,736; 2004—32,115; and 2005—not available. More information can be found in table 12.

[8]Reported figure.

[9]Reported by Eramet for Sandouville. Excludes secondary production from spent rechargeable batteries.

[10]Nickel metal production for the Republic of Korea and Taiwan are not included because the production is derived wholly from imported metallurgical-grade oxides and to include them would result in double counting. Metal estimates are as follows, in metric tons: Republic of Korea: 2001—26,429; 2002—30,337; 2003—31,340 (revised); 2004—27,200 (revised); and 2005–26,300 (estimated). Taiwan: 2001—11,500 and 2002-05—11,000.

[11]Nickel content of nickel sulfate ($NiSO_4 \bullet 6H_2O$). Most of the nickel sulfate was a byproduct of the concentrating, smelting, and refining of domestically mined copper ores. Some production, however, may have been derived from imported nickeliferous raw materials that were blended with the domestic copper concentrates.

[12]Includes nickel sulfate plus exported metal in concentrate.

[13]May include nickel in remelt alloys derived from scrap.

[14]Data represent production from domestic nickel ore.

[15]Previously published as "Other, metal." Data represent production from matte imported from Botswana as well as nickel sulfate imported from South Africa.

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TABLE 12

NICKEL: WORLD PRODUCTION OF INTERMEDIATE PRODUCTS FOR EXPORT, BY COUNTRY[1, 2]

(Metric tons of contained nickel)

Country	2001	2002	2003	2004	2005
Matte:					
Australia[3]	34,978	25,762	38,216	32,256 r	44,536
Botswana	22,454	23,896	27,400	22,292	20,000 e
Brazil[4]	10,183	6,274 r	5,950 r	6,708 r	6,710 p
Canada[e, 5]	48,000	50,000	45,000	58,000 r	60,000
China, exports[e, 6]	--	--	4,530	20	26
Indonesia[7]	62,600	59,500	70,200	72,200 r	76,400
New Caledonia	13,061	11,217	10,857	11,857	12,838
Russia[8]	--	7,783	3,866	599	600
Total	191,000	184,000	206,000	204,000 r	221,000
Other, Cuba:[9]					
Sulfide precipitate	29,914	30,858	30,198 r	31,860 r	32,000 e
Ammoniacal liquor precipitate	1,957 r	1,746	1,502 r	1,842 r	1,900 e
Total	31,871 r	32,604	31,700 r	33,702 r	33,900 e

eEstimated. pPreliminary. rRevised. -- Zero.

[1]Table includes data available through July 22, 2006. Data represent nickel content of matte and other intermediate materials produced for export.

[2]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[3]Total matte production on a contained nickel basis, in metric tons, was as follows: 2001—96,550; 2002—91,574; 2003—107,000; 2004—108,000 (estimated); and 2005—96,000. Figures exclude toll-refined material.

[4]Represents the output of the Fortaleza smelter. All of the Fortaleza matte is being shipped to Finland for further processing.

[5]Estimated nickel content of reported exports. Matte from the Falconbridge smelter of Falconbridge Limited typically assays 55% nickel.

[6]Chinese exports were estimated to have a nickel content of 63%. Total matte production on a contained nickel basis, in metric tons, was estimated as follows: 2001—59,000; 2002—59,200; 2003—69,300; 2004—74,000 (revised); and 2005–75,000.

[7]Represents the nickel output of the Soroako smelter. The Soroako matte, which also contains cobalt, is being shipped to Japan for further processing.

[8]Russian figures reported primarily for exports to China from 2002 to 2004. Source: United Nations Statistics Division.

[9]Corrected for coproduct cobalt.

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TABLE 13
NICKEL: NEW LATERITE PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, BEFORE 2020

(Metric tons unless otherwise specified)

Projected year of first production	Country and state/province	Project and company[1]	Resource grade (% Ni)	Estimated resources (thousands)[2]	Annual production capacity (contained Ni)	Nickel product
2005	Philippines	Adlay-Cagdianao-Tandawa	1.61	5,800	5,000	Ore.
	(Surigao del Norte)	BHP Billiton Group and Case Mining and Development Corp.	1.58	13,000		
2005	Philippines	Rio Tuba	1.26	16,000	10,000	Ni-Co sulfide.
	(Palawan)	Coral Bay Nickel Corp. (Sumitomo consortium)				
2007	Do.	Berong	2.30	4,200	17,000	Ore.
	Do.	Toledo Mining Corp. PLC, Atlas Consolidated Mining and Development Corp., Investika Ltd.	1.30	270,000		
2007	Turkey	Caldag	1.32	23,000	21,000	Leachate precipitate.
	(Manisa)	European Nickel PLC and BHP Billiton Group	1.26	17,600		
			1.32	7,100		
2008	Australia	Ravensthorpe	0.75	118,000	50,000	Ni-Co hydroxide.
	(Western Australia)	BHP Billiton Group	0.60	120,000		
2008	New Caledonia	Goro	1.34	96,000	60,000	Ni oxide.
	(Southern)	Goro Nickel S.A.	2.01	24,000		
		CVRD Inco Limited, Société de Participation Minière du Sud Calédonien S.A.S., Sumitomo consortium	1.70	83,000		
2009	Australia	Jump-up Dam	1.07	19,000	5,000	Leachate precipitate.
	(Western Australia)	Heron Resources Ltd.	0.82	22,000		
2009	Brazil	Onca-Puma	1.86	78,000	57,000	Ferronickel.
	(Para)	Mineração Onça Puma	1.25	91,000		
		Companhia Vale do Rio Doce				
2010	Brazil	Barro Alto	1.85	23,000	36,000	Do.
	(Goias)	Anglo American plc	1.79	7,000		
2010	Brazil	Vermelho	0.80	290,000	46,000	Metal or oxide.
	(Para)	Companhia Vale do Rio Doce				
2010	Guatemala	Fenix saprolite (pyrometallurgical process)	1.81	8,700	22,700	Ferronickel.
	(Izabal)	Skye Resources Inc. and CVRD Inco Ltd.	1.58	33,000		
2011	Australia	Marlborough/Gladstone	0.94	49,000	60,000	Metal.
	(Queensland)	Gladstone Pacific Nickel Ltd.	0.93	6,000		
2011	Cuba	Pinares de Mayari West	1.10	400,000	40,000	Metal, oxide, or ferronickel.
	(Holguin)	Government of Cuba				
2011	Kazakhstan	Shevchenko	0.85	21,000	15,700	Ferronickel.
	(Kostanai Oblast)	Oriel Resources plc	0.77	83,000		
2011	New Caledonia	Koniambo	2.40	63,000	60,000	Do.
	(Northern)	Xstrata Nickel and Soc. Miniere du Sud Pacifique S.A.	2.47	13,000		
			1.60	100,000		
2011	Papua New Guinea	Ramu	0.91	76,000	33,000	Ni-Co intermediate.
	(Madang)	China Metallurgical Construction (Group) Corp., Highlands Pacific Ltd., and Mineral Resources Development Co.	1.01	67,000		
2012	Australia	Young	0.99	58,000	4,500	Leachate precipitate, initially.
	(New South Wales)	Jervois Resources Ltd.	0.72	110,000		
			0.38	110,000		
2012	Cuba	Las Camariocas	1.32	110,000	22,500	Metal, oxide, or ferronickel.
	(Holguin)	Government of Cuba and others[3]				
2012	Guatemala	Fenix limonite (hydrometallurgical process)	1.18	33,000	22,200	Ni-Co hydroxide.
	(Izabal)	Skye Resources Inc. and CVRD Inco Ltd.				
2012	Indonesia	Weda Bay (Santa Monica, Pintu, Boki Mokot deposits)	1.45	154,000	48,000	Ni-Co sulfide.
	(Halmahera Island)	Weda Bay Minerals Inc. (Eramet Group) and PT Aneka Tambang	1.53	123,000		
2012	Madagascar	Ambatovy (Ambatovy and Analamay deposits)	1.12	44,000	60,000	Ni-Co intermediate.
		Dynatec Corp., Sumitomo Corp., South Korean Consortium	0.99	81,000		

See footnotes at end of table.

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TABLE 13—Continued
NICKEL: NEW LATERITE PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, BEFORE 2020

(Metric tons unless otherwise specified)

Projected year of first production	Country and state/province	Project and company[1]	Resource grade (% Ni)	Estimated resources (thousands)[2]	Annual production capacity (contained Ni)	Nickel product
2013	Australia (Western Australia)	Mount Margaret Minara Resources Ltd.	0.78	170,000	45,000	Ni-Co hydroxide.
2013	Guatemala	Sechol (El Inicio, El Segundo, Rio Negro, Poza Azul deposits) Jaguar Nickel S.A. (BHP Billiton Ltd.)	1.40 1.50	37,000 [4] 100,000	NA	Ni-Co intermediate.
2013	Philippines (Mindoro Island)	Sablayan (Kisluyan, Buraboy, Shabo areas) Crew Minerals ASA	0.94 0.95 0.88	73,000 47,000 88,000	60,000	Ni-Co sulfide.
2014	Australia (New South Wales)	Syerston Ivanhoe Nickel and Platinum Ltd.	0.73	77,000	18,000	Ni-Co sulfide concentrate.
2014	Australia (Western Australia)	Kalgoorlie and North Kalgoorlie—Ghost Rocks, Goongarrie, Kalpini Heron Resources Ltd. and Inco Limited	1.20 0.83	100,000 225,000	50,000	Ni-Co hydroxide.
2014	Cuba (Camaguey)	San Felipe Government of Cuba and others	1.30	250,000	45,000	Metal or oxide.
2015	New Caledonia (Southern)	Prony CVRD Inco Limited, Bureau de Recherches Geologiques et Minieres, Sumitomo consortium	1.50	NA [4]	NA [4]	Ni oxide.
2016	Papua New Guinea (Oro)	WoWo Gap Resource Mining Corp. Ltd.	1.09 1.44	31,000 18,000	45,000	Metal.
2017	New Caledonia (Northern)	Nakety-Bogota Argosy Minerals, Inc. and Soc. des Mines de la Tontouta	1.47 1.50	88,000 140,000	52,000	Ni-Co intermediate.
2019	Dominican Republic (Las Jarditas)	Cerro de Maimon (Cumpie Hill and Loma Mala) Rio Tinto plc	1.70	NA	NA	NA
2019	Indonesia (Sulawest)	La Sampala Rio Tinto plc	1.50 1.30	195,000 185,000	46,000	NA
2020	Côte d'Ivoire	Biankouma, Touba, Sipilou Xstrata Nickel and Soc. d'Etat pour le Developpement Minier	1.57 1.40	120,000 140,000	45,000	Ni-Co intermediate or ferronickel.
2020	Indonesia (Maluku)	Gag Island BHP Billiton Group and PT Aneka Tambang	1.35	240,000	30,000	Intermediate, metal, or ferronickel.

NA Not available.

[1]Company names reflect organizational structure as of February 26, 2007. BHP Billiton Group is a dual listed company comprising of BHP Billiton Limited and BHP Billiton Plc.

[2]Gross weight, dry. "Estimated resources" are rounded to no more than two significant digits. When two or more data sets are listed, the first resource data represent measured resources; the second, indicated resources; and the third, inferred resources.

[3]China Minmetals Corporation and the Government of Venezuela have both expressed an interest in investing in this long-stalled project.

[4]New resource estimate in progress.

Sources: Company annual reports, presentations, and press releases; CRU International, Ltd.

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TABLE 14
NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, BEFORE 2020

(Metric tons unless otherwise specified)

Projected year of first production	Country and state/province	Project and company[1]	Resource grade (% Ni)	Estimated resources (thousands)[2]	Annual production capacity (contained Ni)	Nickel product
2005	Canada	Voisey's Bay	2.75	32,000	50,000	Concentrates, initially.
	(Labrador)	CVRD Inco Ltd.	1.89	40,000		
			1.90	6,000		
2006	Australia	Forrestania-Flying Fox, New Morning and Digger	5.59	1,200	7,000	Concentrates.
	(Western Australia)	South	1.84	1,700		
		Western Areas NL	4.50	26		
2006	Do.	Lanfranchi	2.61	1,200	6,300	Ore.
	Do.	Sally Malay Mining Ltd. and Donegal Resources Ltd.				
2006	Do.	Waterloo and Amorac	3.50	299	10,000	Concentrates.
	Do.	LionOre Australia Ltd.				
2007	Australia	Avebury	1.16	4,400	5,700	Do.
	(Tasmania)	Allegiance Mining NL	1.00	8,400		
2008	Canada	Podolsky, '2000', and Whistle Pit	0.30	3,200	NA	Ore.
	(Ontario)	FNX Mining Company, Inc.	0.39	1,200		
2008	United States	NorthMet	0.11	810,000	7,100	Byproduct concentrate of Ni-Co hydroxide.
	(Minnesota)	PolyMet Mining Corp.				
2009	Australia	Cosmos South, Alec Mairs, Anomaly 1	0.74	36,000	10,000	Concentrates.
	(Western Australia)	Jubilee Mines NL				
2009	Canada	Nickel Rim South	1.80	13,000	10,000	Do.
	(Ontario)	Xstrata Nickel				
2009	Finland	Kylylahti copper-cobalt	0.20	7,400	1,000	Ni-Co hydroxide.
		Vulcan Resources Limited				
2009	Tanzania	Kabanga	2.60	26,000	30,000	Do.
	(Kagera region)	Barrick Gold Corp. and Falconbridge Limited				
2009	Vietnam	Ban Phuc	2.40	1,010	4,000	Do.
		Asian Mineral Resources Limited	2.77	220		
2009	Zambia	Munali	1.40	4,500	8,000	Do.
		Albidon Limited	1.40	2,400		
2010	Australia	Sherlock Bay	0.49	33,000	8,500	Precipitated leachate.
	(Western Australia)	Australasian Resources Ltd.				
2010	United States	Eagle	3.80	3,600	NA	Ore.
	(Michigan)	Kennecott Minerals Company	2.20	500		
2011	South Africa	Sheba's Ridge	0.18	409,000	23,700	Concentrates.
	(Mpumalanga)	Ridge Mining plc and Anglo Platinum Ltd.	0.18	313,000		
			0.17	53,000		
2012	Australia	Honeymoon Well and Avalon (Bulong)	0.65	120,000	40,000	Concentrates, initially.
	(Western Australia)	LionOre Australia Ltd. and OM Group, Inc.	0.65	120,000		
2012	Do.	Yakabindie	0.58	290,000	40,000	Ore.
	Do.	BHP Biliton Group				
2012	Canada	Maskwa	0.64	8,100	3,800	Do.
	(Manitoba)	Mustang Minerals Corp.	0.46	990		
2012	Russia (Amur)	Kun-Manie (Vodorazdelny, Ikensoe, Maly	0.61	3,700	NA	NA
		Krumkon, and Falcon)	0.47	33,000		
		Amur Minerals Corp.	0.47	17,000		
2012	United States	Mesaba	0.12	300,000	20,000	Byproduct concentrate of Ni-Co sulfide or hydroxide.
	(Minnesota)	Teck Cominco American, Inc.				
2012	Zimbabwe	Hunters Road	NA	(2)	NA	Ore.
		Bindura Nickel Corp.				
2014	Canada (Ontario)	Totten	0.74	6,000	3,800	Concentrates.
		CVRD Inco Ltd.	0.75	550		
2015	Canada (Quebec)	South Raglan (Mesamax, Mequillon, Expo, Ivakkak, TK deposits)	1.00	11,000	NA	Do.
		Canadian Royalties Inc.	1.60	950		

See footnotes at end of table.

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TABLE 14—Continued
NICKEL: NEW SULFIDE PROJECTS SCHEDULED FOR COMPLETION, BY YEAR, BEFORE 2020

(Metric tons unless otherwise specified)

Projected year of first production	Country and state/province	Project and company[1]	Resource grade (% Ni)	Estimated resources (thousands)[2]	Annual production capacity (contained Ni)	Nickel product
2017	Canada (Ontario)	Kelly Lake CVRD Inco Ltd.	NA	NA	NA	Concentrates.
2018	Do.	Victoria FNX Mining Company Inc.	NA	(3)	NA	Ore.

NA Not available.

[1]Company names reflect organizational structure as of February 26, 2007. BHP Billiton Group is a dual listed company comprising of BHP Billiton Limited and BHP Billiton Plc.

[2]Gross weight, dry. "Estimated resources" are rounded to no more than two significant digits. When two or more data sets are listed, the first resource data represent measured resources; the second, indicated resources; and the third, inferred resources.

[3]Resource estimate in progress.

Sources: Canadian Minerals Yearbook 2004; company annual reports, presentations, and press releases; and CRU International, Ltd.

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NITROGEN

By Deborah A. Kramer

Domestic tables were prepared by Nicholas A. Muniz, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

In 2005, U.S. ammonia production was 8.04 million metric tons (Mt) of contained nitrogen, about an 11% decrease from production in 2004. Volatile natural gas prices that resulted from the hurricanes that hit the U.S. Gulf Coast in August and September led to temporary and permanent closures of U.S. ammonia facilities. Apparent consumption was about 2% less than that in 2004. Imports of ammonia were about 10% higher than those in 2004, with most of the imports in 2005 coming from Canada, Trinidad and Tobago, and Ukraine. About 90% of the domestically produced ammonia consumed in the United States was used in fertilizer applications. Global ammonia production in 2005 of 121 Mt of contained nitrogen was about 3% higher than that in 2004. China, India, Russia, and the United States were the leading producers, together accounting for about 55% of the total.

Legislation and Government Programs

The Energy Policy Act of 2005 (Public Law 109-58) was signed by the President on August 8. One of the provisions in the law requires that gasoline sold in the United States contain specified quantities of ethanol, increasing from 4.0 billion gallons in 2006 to 7.5 billion gallons by 2012 (U.S. Congress, 2005). Because ethanol is derived primarily from corn, increased corn production for ethanol would lead to increased nitrogen fertilizer use.

In its sunset reviews of antidumping duties on urea from Russia and Ukraine, the U.S. Department of Commerce, International Trade Administration (ITA) determined that revocation of the antidumping orders would lead to a continuation or recurrence of dumping. As a result, the antidumping duties on urea from Russia and Ukraine remained at 53.23% ad valorem for Phillip Brothers Ltd. and 68.26% ad valorem for all other exporters (U.S. Department of Commerce, International Trade Administration, 2005a, b).

In April, the ITA also initiated a sunset review of antidumping duties on ammonium nitrate from Russia. This investigation was expected to be completed by early 2006. The ITA had suspended the antidumping duty investigation on ammonium nitrate from Russia effective May 19, 2000, because of an agreement between the ITA and Russia's Ministry of Trade. Under this agreement, the Ministry agreed to restrict exports of ammonium nitrate from all Russian producers and exporters to the United States and to ensure that such exports are sold at or above an agreed reference price.

Production

Industry statistics for anhydrous ammonia and derivative products were developed by the U.S. Census Bureau. A summary of the production of principal inorganic fertilizers by quarter was reported in the series MQ325B. The report on industrial gases (including nitrogen), MQ325C, was discontinued at the end of 2004. In 2005, production of anhydrous ammonia (82.2% nitrogen) fell by 11% to 8.04 Mt of contained nitrogen compared with a revised figure of 8.99 Mt in 2004 (table 1). Of the total production, 90% was for use as a fertilizer; the remaining 10% was used in other chemical and industrial sectors (table 2).

The United States was a leading producer and consumer of elemental and fixed types of nitrogen. In declining order, ammonium phosphates [diammonium phosphate (DAP) and monoammonium phosphate], urea, ammonium nitrate, nitric acid, and ammonium sulfate were the major downstream products produced from ammonia in the United States. Their combined production was 8.91 Mt of contained nitrogen, with ammonium phosphates and urea each accounting for about 27% of the production (table 3).

Ammonia producers in the United States operated only at about 61% of design capacity in 2005; this percentage included capacities at plants that operated during any part of the year and does not include plants that were idle for all of 2005. Of the total available U.S. ammonia production capacity, almost 55% was concentrated in the States of Louisiana (33%), Oklahoma (16%), and Texas (6%) where there are large reserves of feedstock natural gas. Koch Nitrogen Co., Terra Industries Inc., CF Industries Inc., Agrium Inc., and PCS Nitrogen Inc., in descending order, accounted for 81% of total U.S. ammonia production capacity (table 4).

The Henry Hub natural gas price experienced wild swings and a significant increase, which resulted in the shutdown of several U.S. ammonia production facilities, particularly in the second half of 2005. The Henry Hub price ranged from a low of $5.53 per million British thermal units at the beginning of the year to a high of $15.27 per million British thermal units at the end of September—nearly a $10 increase. The increased cost of natural gas primarily was the result of refinery shutdowns caused by Hurricanes Katrina and Rita. Although structural damage to ammonia plants from the Gulf Coast hurricanes was minimal, two were closed because of a disruption in natural gas supplies. Terra Industries' Yazoo City, MS, nitrogen facility was shut down for the first 2 weeks of September, and El Dorado Chemical Co.'s Cherokee, AL, facility was closed for about 1 month.

In May, Terra Industries announced that it would mothball its 454,000-metric-ton-per-year (t/yr) Donaldsonville, LA, ammonia plant. The plant was acquired from Mississippi Chemical Corp. in 2004 and had last operated in December 2004. Mississippi Chemical had operated the plant as a swing ammonia producer, and Terra Industries determined that volatile natural gas prices had made operating the facility as a swing producer uneconomical. Before its sale to Terra Industries, Mississippi Chemical had closed a separate ammonia and urea plant at the Donaldsonville site, and the second closure

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completed the transition from a manufacturing facility to a facility used only as a storage and distribution terminal. Terra Industries also announced that it would purchase ammonia from Yara International ASA for delivery to Donaldsonville. The purchase quantities were about the same as the mothballed production capacity (Green Markets, 2005i).

In November, Terra Industries announced that it had indefinitely suspended ammonia production at its 399,000-t/yr Woodward, OK, facility. The plant would undergo mechanical repairs and catalyst changes, but would not reopen because of high natural gas costs (Green Markets, 2005j). In December, Agrium announced that it would close its 490,000-t/yr Borger, TX, ammonia facility because of high natural gas prices. By the end of 2005, CF Industries was operating its 2.04-million-metric-ton-per-year (Mt/yr) Donaldsonville ammonia plant at 50% of its rated capacity, Dakota Gasification Co.'s 363,000-t/yr Beulah, ND, ammonia facility was offline, and several other plants were operating at reduced capacity (Green Markets, 2005d).

After several months of negotiations, Agrium completed a natural gas supply contract with Alaska's Cook Inlet producers in July that would allow the company to continue operating its Kenai, AK, ammonia plant at one-half its 1.25-Mt/yr capacity through November 2006. Agrium's contract with Unocal Corp. for natural gas for the plant was set to expire on October 31, 2005 (Green Markets, 2005c). Because of the tenuous supply of natural gas, Agrium planned to conduct a feasibility study on the potential use of coal gasification products as feedstock for the Kenai nitrogen complex. The proposed project would use local low-sulfur coal to produce feedstock, generate electricity that could be sold, and generate carbon dioxide that could be used in gas and oil exploration (Green Markets, 2005b). Agrium also was investigating constructing a nitrogen complex in Egypt to replace the Kenai plant. The company had an agreement on natural gas supply with the Egyptian Government and was expected to reach a decision by mid-2006 (Fertilizer Week, 2005i).

Rising security costs and concerns prompted some companies to stop marketing ammonium nitrate. In January, J.R. Simplot Co. announced that it would discontinue marketing fertilizer-grade ammonium nitrate to its United States and Canadian customers after the spring planting season. As a result of this decision, the company's Brandon, Manitoba, Canada, plant, which supplied these markets, would increase production of its other products—urea ammonium nitrate (UAN) solutions and urea—and produce only a small quantity of ammonium nitrate for blending (Green Markets, 2005h). In July, Agrium announced that it would discontinue production and sales of fertilizer-grade ammonium nitrate. The company produced ammonium nitrate at its Beatrice, NE, facility (Green Markets, 2005a). Wilbur-Ellis Co., an international distributor of agricultural products, also announced that it would no longer market ammonium nitrate for fertilizer applications as of December 31, 2005, and Air Products and Chemicals Inc. was looking for a buyer for its Pace, FL, ammonium nitrate production facility (Green Markets, 2005l). Yara North America Inc. announced that it would stop selling fertilizer-grade ammonium nitrate in California because of security concerns and rising cost associated with security regulations. By yearend, the only firms producing ammonium nitrate in the United States were El Dorado and Terra Industries.

Environment

Hypoxia has become a controversial environmental concern for the fertilizer industry and an issue that spawned significant research efforts to determine its cause. Hypoxia refers to the phenomenon that happens where water near the bottom of an affected area contains less than 2 parts per million of dissolved oxygen. Hypoxia can cause stress or death in bottom-dwelling organisms that cannot move out of the hypoxic zone. Some studies postulated that nitrate runoff from fertilizers is the principal cause of hypoxia, while others cited other causes for the hypoxic zone.

Consumption

In 2005, apparent consumption of ammonia of 14.1 Mt of contained nitrogen was about 2% lower than that in 2004. Apparent consumption is calculated as the production plus imports minus exports, adjusted to reflect any changes in stocks. Consumption of nitrogen fertilizers in the United States for the 2005 crop year (ending June 30, 2005) is listed in table 5. Consumption of 11.3 Mt of contained nitrogen was about 5% lower than that of 2004. Anhydrous ammonia and nitrogen solutions, mostly UAN containing 29.8% to 29.9% nitrogen, were the principal fertilizer products, each representing 25% of fertilizer consumption. Urea (45.9% nitrogen) constituted 19% of fertilizer consumption during the 2005 crop year. Ammonium nitrate containing 33.9% nitrogen constituted 4% of 2005 nitrogen fertilizer consumption, and fertilizer consumption of ammonium sulfate, based on nitrogen content, was 2% of the total U.S. nitrogen-base fertilizer market. The leading nitrogen-consuming States in the 2005 crop year were, in descending order, Iowa, Illinois, Nebraska, Kansas, and California. Together, these five States accounted for 38% of the nitrogen-containing fertilizer consumption in the United States.

Stocks

Stocks of ammonia at yearend 2005 were 197,000 metric tons (t), a decrease of 34% from comparable stocks at yearend 2004, according to data published by the U.S. Census Bureau (table 6).

Transportation

Ammonia was transported by refrigerated barge, rail, pipeline, and truck. Three companies served 11 States with 5,090 kilometers (km) of pipelines and 4,800 km of river barge transport; rail and truck were used primarily for interstate or local delivery.

Valero L.P. operated the Gulf Central ammonia pipeline. The 3,200-km pipeline originates in the Louisiana Delta area and has access to three marine terminals. It moves north through Louisiana and Arkansas into Missouri, where it splits at Hermann, MO, one branch going east into Illinois and Indiana and the other branch continuing north into Iowa and then turning west into Nebraska. The capacity of this pipeline was about 2 Mt/yr, with a storage capacity of more than 1 Mt. CF Industries and Cargill Fertilizer Inc. jointly operated the 135-km Tampa Bay Pipeline (TBP) system. The TBP moved nitrogen compounds and ammonium phosphate for fertilizer producers in Hillsborough and Polk Counties, FL. Magellan Midstream Partners LP's 1,750-km ammonia pipeline,

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which originates at production facilities in Borger and in Verdigris and Enid, OK, and terminates in Mankato, MN, has a maximum delivery capacity of about 820,000 t/yr. It transports ammonia to 13 delivery points along the pipeline system and has a storage capacity of about 500,000 t. In 2005, 692,000 t of ammonia was shipped through Magellan's pipeline, compared with 646,000 t in 2004 (Magellan Midstream Partners L.P., 2006§[1]).

Prices

Midyear and yearend prices for nitrogen materials are listed in table 7, and the relationship between the natural gas price and Gulf Coast ammonia price is shown in figure 1. Natural gas prices increased significantly as a result of the damage caused to the U.S. refining industry by the Gulf Coast hurricanes in August and September. Hurricane Katrina caused significant direct damage to offshore rigs, refineries, pipelines, and ports in the Gulf of Mexico, accompanied by wide-scale electricity outages and flooding. Katrina initially reduced natural gas supplies by an estimated 8.8 billion cubic feet per day because of shut-ins as well as direct damage. Hurricane Rita resulted in more than a dozen natural gas processing plants going offline because of flooding, a lack of supplies, an inability to move stored liquids, or safety precautions. Natural gas pipelines sustained significant damage, and the Sabine Pipeline (operator of the Henry Hub) implemented a force majeure. By the end of December, the U.S. Department of Energy (DOE), Energy Information Administration (2006a§) reported that approximately 19.5% of Federal Gulf of Mexico natural gas production remained shut-in because of Hurricanes Katrina and Rita.

Average Gulf Coast ammonia prices began the year at $285 per short ton ($314 per metric ton), fell through January to reach a low for the year of $215 per short ton ($237 per metric ton) at the end of the month. Prices rose through February and March, then leveled off. After the hurricanes hit the Gulf Coast, prices increased rapidly to reach the high for the year of $403 per short ton ($444 per metric ton) by the beginning of November. By the end of 2005, the average ammonia price had fallen to $360 per short ton ($397 per metric ton)

Granular urea prices rose fairly steadily though 2005. At the beginning of the year the price was $224 per short ton ($247 per metric ton). The price reached its high for the year of $278 per short ton ($306 per metric ton) at the beginning of October, then fell slightly to end the year at $264 per short ton ($291 per metric ton).

Ammonium nitrate prices increased slowly for the first half of 2005. The average price increased from its low of $203 per short ton ($224 per metric ton) at the beginning of the year and stabilized at $225 per short ton ($248 per metric ton) at the beginning of June. After the hurricanes, the price immediately rose by $50 per short ton and continued to increase until it reached $268 per short ton ($295 per metric ton) at yearend, which was the high price for the year.

Ammonium sulfate prices, however, did not follow the upward trend of other nitrogen products, mainly because a substantial portion of the material is produced as a byproduct of caprolactam production. The average price rose steadily through the end of May from $185 per short ton ($204 per metric ton) to its high for the year of $214 per short ton ($236 per metric ton). It remained at this level until mid-July, when it fell by about $40 per short ton, then continued to increase to a yearend price of $198 per short ton ($218 per metric ton).

Foreign Trade

Ammonia exports were about 38% higher than those in 2004 (table 8). The Republic of Korea continued to be the leading destination for U.S. exports of ammonia, accounting for 86% of the total. Most of the material shipped to the Republic of Korea was produced at the Agrium plant in Alaska.

Ammonia imports were 10% higher than those in 2004 and were more than 12 times greater than the quantity of exports. The average value of ammonia imports increased to $310 per metric ton from $262 per metric ton in 2004 (table 9). Trinidad and Tobago (57%) continued to be the leading import source. Canada (17%) and Ukraine (15%) were the remaining significant import sources.

Tables 10 and 11 list trade data for other nitrogen materials and include information on principal source or destination countries. Exports of nitrogen materials declined in 2005, with the exception of ammonia and DAP. Changes in import quantities of nitrogen materials were mixed compared with imports in 2004. In general, the materials with the largest quantity of imports (ammonia, nitrogen solutions, and urea) had increased imports from those in 2004.

World Review

Anhydrous ammonia and other nitrogen materials were produced in more than 80 countries. Global ammonia production in 2005 of 121 Mt was about 3% higher than that of 2004 (table 12). A significant portion of this increase resulted from a 3.0-Mt increase in production from China, which, with 31% of total production, was the leading world producer of ammonia. Asia contributed 49% of total world ammonia production, and the Commonwealth of Independent States (CIS), Estonia, and Lithuania produced 14% of the global total. North America represented 10% of the total; Western Europe, 8%; Central America and South America and the Middle East, 6% each; and Africa, Eastern Europe, and Oceania together contributed the remaining 7%.

Algeria.—Spain's Fertiberia S.A. planned to invest $316 million to build a new 1.1-Mt/yr ammonia plant in Arzew. Plant completion was scheduled for 2009. Fertiberia operated a 370,000-t/yr ammonia plant near Huelva, Spain (Nitrogen & Methanol, 2005).

Argentina.—Profértil S.A. announced that it would invest $60 million to construct a UAN solution plant at Bahia Blanca. The company planned to use ammonia from the existing nitrogen complex at the site to produce nitric acid, which is required to produce UAN solution. Profértil estimated that the plant's capacity could reach 500,000 t/yr of UAN solution in 2007 (Fertilizer Week America, 2005).

Australia.—In April, Burrup Fertilisers Pty. Ltd. announced that it was considering building a second fertilizer plant in Western Australia that would be at least twice the size of its $630 million 760,000-t/yr ammonia plant nearing completion on the Burrup Peninsula. Burrup was evaluating potential plant sites in Western Australia and the Middle East, but the final location would

[1]References that include a section mark (§) are found in the Internet References Cited section.

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depend on competitive gas supplies. The second project would incorporate two trains and also produce urea and ammonium nitrate. Preliminary talks with prospective suppliers had begun, and a feasibility study would take at least 12 to 14 months to complete from July, suggesting a production startup toward the end of the decade. In addition, Norway's Yara International, which had an offtake agreement for 100% of the ammonia produced from Burrup's nearly completed plant, acquired a 30% stake in Burrup for about $100 million (Burrup Fertilisers Pty. Ltd., 2005§).

In November, Wesfarmers Ltd. announced that it would double its ammonium nitrate production at Kwinana, Western Australia, to 470,000 t/yr by 2007. The cost of the expansion was estimated to be $146 million. More than one-half of the plant's output would be explosives-grade ammonium nitrate, and the rest would be used to make a variety of liquid fertilizers (Fertilizer Week, 2005l).

Bulgaria.—Two rehabilitation plans were submitted for nitrogen producer Chimco AD subject to approval by Chimco's creditors. Novo Chimco AD's plan included delivery of gas directly to the plant from Russia's Gazexport. Inter RAO Bulgaria (a subsidiary of Russian company RAO United Energy Systems) submitted a separate rehabilitation plan for the fertilizer plant. The main creditors of Chimco included the state-owned gas supplier Bulgargaz EAD and National Electric Co. (Sofia Echo, 2005§). After a September 30 meeting, creditors of Chimco chose the rehabilitation scheme submitted by Novo Chimco over that of Inter RAO Bulgaria. Chimco's debt to Bulgargaz and National Electric, totaling lev151 million ($92.2 million), will be reset for 18 years. In return, Novo Chimco will become sole owner, and the shares of 7,000 small investors will be canceled (Internet Bankruptcy Library, 2005§).

Canada.—Methanex Corp. announced that it would close its Kitimat, British Columbia, 280,000-t/yr ammonia and 500,000-t/yr methanol plants on November 1 because of the volatile cost of natural gas. The plant was shut down 2 months earlier than the planned date of January 2006 because Methanex reached an agreement with Mitsui & Co., Ltd., which was Methanex's buyer of ammonia produced at Kitimat. The company planned to convert the site to a terminal operation (Green Markets, 2005g).

Egypt.—The U.S. Export-Import Bank approved a $229.8 million long-term guarantee to support construction of a $540 million ammonia plant in Egypt by Kellogg, Brown and Root (a subsidiary of Halliburton Inc.) and other United States companies. The new plant will be constructed for Egypt Basic Industries Corp. and will produce 2,000 metric tons per day (t/d) of ammonia. Kellogg, Brown and Root, PSK Holdings (an Egyptian petrochemical company), Orascom Construction Industries (an Egyptian construction firm), and Egyptian General Petroleum Corp. (the state-owned oil and gas company) were expected to be the plant's owners. In October, Orascom invested $57 million in the project to become the leading shareholder, with a 30% stake. The planned facility, which was expected to be completed by 2008, will be connected by pipeline to product storage tanks in Sokhna Port (Green Markets, 2005k).

Georgia.—In March, Georgia's Ministry of Economic Development announced that nitrogen producer RustaviAzot would be offered for privatization, with expressions of interest due to the Ministry by May 2. Russian energy firm Itera Holdings Ltd. had taken a 90% ownership in RustaviAzot in 2002 for $0.5 million, which was conditional on investing $13.7 million in the facility during 2 years of ownership and writing off a $46 million gas supply debt. The Georgian Government said that none of these financial obligations had been honored, and Itera claimed that the Georgian Government did not honor its obligation to pay off its debt to Itera, which was estimated to be $60 million. By yearend, no determination on privatization had been resolved (Fertilizer Week, 2005e).

India.—Deepak Fertilisers and Petrochemicals Corp. Ltd. announced plans to construct a 300,000-t/yr ammonium nitrate plant in eastern India. The company planned to supply the domestic mining and construction industries and similar markets in Southeast Asia and Australia. Estimated annual domestic demand for ammonium nitrate was 450,000 t/yr, with domestic production supplying about 265,000 t/yr. The project was expected to require 24 months to complete and would cost $87 million. A final location was not selected, and no timetable was set for the start of construction (Fertilizer Week, 2005c). Deepak operated a 90,000-t/yr ammonium nitrate facility at Taloja.

Rashtriya Chemicals and Fertilizers Ltd. (RCF) planned to invest $453 million in a 2,000-t/d-ammonia and 3,200-t/d-urea plant with power generation, offsite utilities, and product handling facilities at an existing plant site in Thal, Maharashtra State. The company completed a feasibility study, and a proposal was submitted to the Government for approval. RCF also planned to improve energy consumption at its Trombay, Maharashtra State, ammonia and urea complex. This upgrade was expected to be completed by April 2006 (Rashtriya Chemicals and Fertilizers Ltd., 2005§).

Indonesia.—The Indonesian Government received permission from its partners in the Asean Aceh Fertilizer facility (Malaysia, the Philippines, Singapore, and Thailand) to close the plant. The plant was originally opened in 1984 to ensure an adequate supply of urea to member states of the Association of South East Asian Nations, but had been closed for more than 1 year because of a rate dispute with ExxonMobil Corp. and the Indonesian supplier of natural gas (Green Markets, 2005f).

Iran.—Ghadir Urea/Ammonia Petrochemical Co. (a joint venture between Iran's National Petrochemical Co. and Ghadir Investment Co.) started precommissioning work on its ammonia-urea complex in Assaluyeh in December. The complex was expected to begin commercial operation in the first quarter of 2006, with a capacity of 680,000 t/yr of ammonia and 1.08 Mt/yr of urea (Viswanathan, 2005).

Nigeria.—India's Nagarjuna Fertilizers and Chemicals Ltd. (NFCL) reached a preliminary agreement with the Nigerian Government to invest $1.2 billion to construct two urea plants with a capacity of 1 Mt/yr; the Government would build the infrastructure required, including roads and water and electrical generation facilities. NFCL would build the plants in Kwara and Cross River States. The Kwara State government reportedly set aside 100 hectares of land near Jebba for the first plant, for which construction would begin in April 2006. This plant would supply domestic needs. The second plant in Cross River State would provide urea for export because of its proximity to the country's Export Processing Zone (Fertilizer Week, 2005g).

In August, Nigeria's Bureau of Public Enterprises sold Government-owned National Fertiliser Co. of Nigeria for $152

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million to O-Secul Fertiliser Co. Ltd. Several unsuccessful attempts were made in 2003 and 2004 to privatize the operation (BusinessDay Online, 2005§). The plant has been idled since 1995 and had the capacity to produce 1,000 t/d of ammonia and 1,500 t/d of urea.

Oman.—In July, Oman India Fertiliser Co. SAOC's (OMIFCO) new ammonia-urea complex at Sur started commercial production. Design capacity at the plant was 3,500 t/d of ammonia and 5,060 t/d of urea using natural gas as feedstock. The urea and surplus ammonia will be shipped to India. OMIFCO is owned 50% by Oman Oil Co. SAOC, 25% by Indian Farmers Fertiliser Cooperative Ltd., and 25% by Krishak Bharati Cooperative Ltd. (Oman India Fertiliser Co. SAOC, undated §).

Pakistan.—Reliance Export (a consortium between Fatima Group and Arif Habib Group) submitted the highest offer for Pak Arab Fertilizer Ltd., $237.6 million, and was awarded 94.8% of the company by the country's Cabinet Committee on Privatisation. The remaining 5.2% of the company was retained by the workers' union. Pak Arab had the capacity to produce 92,000 t/yr of urea and downstream products, such as calcium ammonium nitrate and nitrophosphates, which were marketed domestically. The consortium planned to increase capacity at the plant at an unspecified future date (Fertilizer Week, 2005d).

Qatar.—Yara International and Qatar Fertiliser Co. (Qafco) signed a letter of intent with Qatar Petroleum Co. to build Qafco-V, a 1-Mt/yr-ammonia and 1.1-Mt/yr-urea plant, which is supported by a new 25-year gas contract between the partners and Qatar Petroleum. A final decision on the project was expected in 2006, with completion scheduled for 2009 or 2010. In mid-2004, Qafco opened Qafco-IV, which brought the company's total production capacity to 2 Mt/yr of ammonia and 2.8 Mt/yr of urea. Qafco was owned 75% by Industries of Qatar and 25% by Yara International. Yara was marketing 50% of the urea produced by Qafco, and the remainder was sold by Qafco (Fertilizer Week, 2005n).

Romania.—At the end of November, the Romanian privatization agency was conducting talks with two bidders for a 79.05% ownership of Nitramonia—Nitrogénmüvek Rt. of Hungary and S.C. Agrosem S.A. Timisoara of Romania. These companies also were bidding for the five subsidiaries S.C. Nitrofertilizer S.A., S.C. Nitroexplosives S.A., S.C. Nitrocontrol S.A., S.C. Nitroservice S.A. and S.C. Nitrotrans S.A. (Authority for State Assets Recovery [Romania], The, 2005§).

Russia.—JSC Acron was planning to invest $1.39 billion in a 10-year modernization of its fertilizer production facilities in Novogorod and Dorogobuzh. Funding was expected to be 50% from profits and 50% from loans from banks in Austria, Germany, and Russia. The fertilizer producer also may sell some shares in the company, which was established in 1967. In Novgorod, Acron was planning to complete a 700,000-t/yr ammonia plant after construction was halted in 1989. By yearend 2005, Haldor Topsøe A/S had almost completed a feasibility study of the $170 million project, which was scheduled for completion in 2008. Together with an existing ammonia unit in Novgorod, total ammonia production will reach 1 Mt/yr. A $25 million urea plant will be upgraded by the end of 2006, adding 150,000 t/yr of capacity to reach a total of 550,000 t/yr. In Dorogubuzh, Acron was planning a $15 million expansion of ammonia production capacity to 550,000 t/yr. It also planned to construct a new 700,000-t/yr ammonia unit during 2008-09 at cost of $245 million. Upgrades and expansions of formaldehyde, melamine, and methanol plants were also scheduled, along with upgrades of power facilities (Fertilizer Week, 2005a). Acron also planned to build an ammonia terminal at one of the Baltic Sea ports to expand export sales. Capacity at the new terminal was expected to be 1 Mt—about one-half would be for storage of Acron's product and the rest would be for storage of ammonia from other Russian producers. At yearend, the company was completing a feasibility study for siting the terminal (Fertilizer Week, 2005b).

Yara International entered a partnership with Russian fertilizer producer OAO Minudobreniya (Rossosh). The agreement included a 30% stock acquisition, technology transfer, and the integration of Rossosh into Yara International's planning and marketing operations. The Rossosh plant, which is based on nitrophosphate technology licensed from Yara International in the early 1980s, has a total production capacity of 800,000 t/yr of ammonia. One-half of the ammonia was upgraded to ammonium nitrate and nitrophosphate fertilizers, and the remainder was sold on the open market. The partnership agreement also will give Yara International access to competitively priced energy and other raw materials (Fertilizer Week, 2005m).

Trinidad and Tobago.—Low natural gas prices in the country, compared with those in the United States, have continued to stimulate interest in developing new ammonia and urea production capacity in Trinidad. In April, Terra Industries announced that Terra Industries, CF Industries, and Trinidad-based ANSA McAL Ltd. were studying the construction of an ammonia-UAN manufacturing facility in Trinidad and Tobago. National Energy Corp. of Trinidad and Tobago Ltd. designated a site for the facility at Union Estate, and the parties have negotiated a long-term natural gas supply with National Gas Co. of Trinidad and Tobago. German engineering firm Uhde GmbH was selected to perform engineering work and estimate the project's cost (Fertilizer International, 2005).

In February, the Government of Trinidad and Tobago signed a memorandum of understanding (MOU) with La Brea Nitrogen Ltd. to construct a $550 million nitrogen complex at Union Estate. Capacity at the plant was projected to be 720,000 t/yr of ammonia, with one-half of the ammonia production upgraded to 915,000 t/yr of UAN. Construction of the new facility was expected to begin by the end of 2005, with completion scheduled for 2008. La Brea Nitrogen was owned by a single family, but the ownership goal was to have 50% owned by local interests (Green Markets, 2005e).

Coffeyville Resources LLC also signed an MOU with the Government of Trinidad and Tobago to construct an ammonia-UAN complex in Union Estate. Total capacity of the plants was projected to be 1.5 Mt/yr of ammonia and 2 Mt/yr of UAN. Costs, technology, and a timetable for construction of the new plants were not announced (Fertilizer Week, 2005f). If the four new plants proposed in 2004 and 2005 are built, the country's ammonia production capacity was expected to increase by 3.4 to 3.5 Mt/yr.

Turkmenistan.—After state-owned Turkmendokunkhimiya's new 600-t/d ammonia and 1,050-t/d urea project at Tedžen was inaugurated in 2004, the country's President announced that an additional 150,000-t/yr of urea capacity was planned. This new plant would produce urea for export (Fertilizer Week, 2005j).

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Construction of a new $74.6 million urea plant with a 400,000-t/yr capacity began in September in Mary Province. The new plant was expected to be commissioned in February 2008. In addition, expansion of the existing ammonia plant would add 200,000 t/yr of production capacity. The total cost of the new construction was estimated to be $210 million (News Central Asia.com, 2005§).

Ukraine.—The Government announced that it intended to privatize the Odessa Port Plant in 2006 for an expected $1 billion. The plant is the second ranked ammonia producer in the country; more than 90% of the plant's output was exported to Europe and the United States (Fertilizer Week, 2005h).

United Arab Emirates.—Oman Chemicals and Pharmaceuticals LLC announced plans to construct a $200 million ammonia and urea plant in Sharjah's Hamriyah Free Zone. The first phase of production of 400,000-t/yr of ammonia was expected to start by April 2007, and phase two production of urea and other products was scheduled to start in 2008. Natural gas for the operation was expected to be purchased for $1.50 per million British thermal units (Nitrogen + Syngas, 2005a)

Ruwais Fertilizer Industries (a joint venture between Abu Dhabi National Oil Co. and Total S.A.) debottlenecked its 610,000-t/yr urea unit and initiated a feasibility study of a $50 million expansion of its facilities to produce ammonia and granulated urea. The additional urea would feed the company's melamine unit (Nitrogen + Syngas, 2005b)

United Kingdom.—Terra Industries announced in November that it suspended ammonia production at its facility at Billingham, Teesside, and it is operating its other facility at Severnside, Bristol, at reduced rates because of the high price of natural gas in the United Kingdom. Terra Industries did not anticipate resuming ammonia production until natural gas costs decrease to a level that allows the ammonia unit to operate with positive cash flow. The company expected to fulfill its British sales commitments from its own inventories and with imported ammonia, some of which would be upgraded to ammonium nitrate (Terra Industries Inc., 2005§). High natural gas prices also prompted the closure of Kemira GrowHow Oyj's 354,000-t/yr Ince ammonia plant during the fourth quarter of 2005.

Venezuela.—In June, Corporatión Petroquímica de Venezuela S.A. (CPV) restarted its El Tablazo ammonia-urea complex that had been idle since 2001, citing rising world ammonia prices as the main reason. CPV restarted one of two ammonia-urea units after a $93 million refurbishment. Ammonia capacity was estimated to be 298,000 t/yr, and urea capacity was estimated to be 360,000 t/yr (Nitrogen + Syngas, 2005c).

Vietnam.—Vietnam National Chemical Corp. received final Governmental approval to construct a coal-based 560,000-t/yr prilled urea plant in northern Ninh Binh Province. The project was expected to cost $400 million and was scheduled to start operations at the end of 2008 or in early 2009. The company had originally planned to build the plant in Bac Gang Province, but the coal transportation infrastructure in Ninh Binh Province was more developed (Fertilizer Week, 2005k).

Current Research and Technology

Researchers at the University of Missouri-Columbia were using light-emitting diodes (LEDs) to measure the color of young corn accurately and apply variable rates of nitrogen according to plant needs. They hope this LED approach will not only increase profits for producers, but also create a healthier environment by minimizing excess nitrogen runoff. In the study, researchers applied an ample amount of nitrogen in early spring to only one area of the field. LED devices mounted on a fertilizer applicator measured light reflected from small (12- to 15-inch) corn plants in this area, providing a reference or baseline point. Variable rates of nitrogen are applied to the rest of the crop by a computer-equipped applicator, depending on the color or reflective value of corn leaves detected by the LEDs (University of Missouri-Columbia, 2005§).

New findings from researchers at the U.S. Department of Agriculture (USDA) Agricultural Research Service show that a beneficial soil fungus plays a large role in nitrogen uptake and utilization in most plants. Arbuscular mycorrhizal fungi transfer substantial amounts of nitrogen to their plant hosts. The researchers discovered a novel metabolic pathway in which inorganic nitrogen is taken up by the fungi and incorporated into the amino acid arginine. Arginine remains in the fungus until it is broken down and transferred to the plant. The results show that the symbiotic relationship between mycorrhizal fungi and plants may have a much more significant role in the worldwide nitrogen cycle than previously believed. As a result, farmers may benefit from promoting the proliferation of mycorrhizal fungi, thereby making more efficient use of the nitrogen stores in agricultural soils (U.S. Department of Agriculture, Agricultural Research Service, 2005§).

Outlook

Corn growers intended to plant 31.6 million hectares (Mha) of corn for all purposes in the 2006 crop year (July 1, 2006-June 30, 2007), 5% less than that in the 2005 crop year (U.S. Department of Agriculture, National Agricultural Statistical Service, 2006§). If this estimate is accurate, this will be the lowest corn acreage planted since the 2001 crop year when 30.6 Mha was planted for all purposes. The forecast for planted corn was lower than that in 2005 in most States because producers intended to switch to other, less input-intensive crops because of high fertilizer and fuel costs. Dry conditions also contributed to lower planting intentions in the southern Great Plains. With these 2006 projections, nitrogen consumption by the fertilizer industry is expected to be slightly lower than that in 2005.

According to long-term projections by the USDA Economic Research Service, projected plantings for the eight major field crops in the United States would increase from the 2005 level of about 98.3 Mha, remaining near 99.2 Mha throughout the projections (U.S. Department of Agriculture, Economic Research Service, 2006§) (figure 2). Yield increases also were projected to contribute to production gains, limiting price increases, and thereby reducing the need for more land to be planted. Corn, soybeans, and wheat would account for about 87% of area planted for the eight major field crops. During the 10-year period, the crop mix was expected to shift to corn and away from soybeans. Corn used to produce ethanol in the United States was projected to more than double by 2015-16 from the 2004-05 level. This increase reflects the effect of the Renewable Fuel Program authorized under the Energy Policy Act of 2005, large ongoing ethanol plant construction, and economic incentives provided by continued high oil prices. (A 51-cent-per-gallon subsidy

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for ethanol producers, which had been enacted in 2004 for production up to 15,000 gallons per year, was extended to production up to 60,000 gallons per year in the 2005 legislation.) Increased feeding of distillers dried grains, a coproduct of dry mill ethanol production, would help meet growing livestock feed demand. Thus, feed use of corn would rise only slowly in the projections.

Natural gas prices are expected to continue to be the most important factor in U.S. ammonia production. If natural gas prices remain at high levels, then ammonia production capacity at older, higher cost plants in the United States will most likely continue to close. (From the beginning of 2001, when natural gas prices began to spike in the winter, until the end of 2005, U.S. ammonia production capacity has declined by 3.7 Mt/yr, or 21% of the 2001 capacity.) The interest that United States firms have shown in constructing new plants outside the United States, particularly in Trinidad and Tobago, indicated that, in the future, much of the United States supply of ammonia was expected to be supplied by foreign production. The DOE projected that, barring extreme weather conditions, spot natural gas prices should ease in 2006, leading to an annual average decline in the Henry Hub price to about $8.11 per million cubic feet ($7.87 per million British thermal units). The respite was expected to be short-lived. The DOE projected that concerns about potential future supply tightness and continuing pressure from high oil prices would drive spot natural gas prices for the next heating season to previous highs, with the Henry Hub spot price rising to about $11.00 per million cubic feet ($10.67 per million British thermal units). The Henry Hub price was expected to average approximately $9.17 per million cubic feet ($8.89 per million British thermal units) in 2007 (U.S. Department of Energy, Energy Information Administration, 2006b§).

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TABLE 1
SALIENT AMMONIA STATISTICS[1, 2]

(Thousand metric tons of contained nitrogen unless otherwise specified)

		2001	2002	2003	2004	2005
United States:						
Production		9,120	10,300	8,450 r	8,990 r	8,040 p
Exports		647	437	400	381	525
Imports for consumption		4,550	4,670	5,720	5,900	6,520
Consumption, apparent[3]		13,200	14,500	13,900 r	14,400 r	14,100 p
Stocks, December 31, producers'		261	286	195 r	298 r	197 p
Average annual price, free on board Gulf Coast[4]	dollars per short ton	183	137	245	274	314
Net import reliance as a percentage of apparent consumption[5]		31	29	39	38	43 p
Natural gas price, wellhead, average price[6]	dollars per thousand cubic feet	4.00	2.95	4.88	5.46 r	7.51 e
World:						
Production		105,000	109,000	110,000	117,000	121,000 e
Trade[7]		12,600	12,900	13,900	14,600	NA

eEstimated. pPreliminary. rRevised. NA Not available.

[1]Data are rounded to no more than three significant digits.

[2]Synthetic anhydrous ammonia, excluding coke oven byproduct; data are for calendar year and are from the U.S. Census Bureau unless otherwise noted.

[3]Calculated from production plus imports minus exports and industry stock changes.

[4]Source: Green Markets.

[5]Defined as imports minus exports; adjusted for industry stock changes.

[6]Source: Monthly Energy Review, U.S. Department of Energy.

[7]Source: International Fertilizer Industry Association Statistics, World Anhydrous Ammonia Trade.

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TABLE 2
ANHYDROUS AMMONIA SUPPLY AND DEMAND IN THE UNITED STATES[1]

(Thousand metric tons of contained nitrogen)

	2003	2004	2005[p]
Production:			
Fertilizer:			
January-June	3,720 [r]	4,240 [r]	4,000
July-December	3,770 [r]	4,230 [r]	3,200
Total	7,490 [r]	8,470 [r]	7,190
Nonfertilizer:			
January-June	535 [r]	273 [r]	305
July-December	426 [r]	251 [r]	537
Total	961 [r]	524 [r]	842
Grand total	8,450 [r]	8,990 [r]	8,040
Imports for consumption:			
January-June	2,890	3,060	3,250
July-December	2,820	2,840	3,270
Total	5,720	5,900	6,520
Exports:			
January-June	234	196	250
July-December	166	185	275
Total	400	381	525
Stocks, end of period:			
January-June	238 [r]	228 [r]	196
July-December	195 [r]	298 [r]	197
Apparent consumption:[2]			
January-June	6,960 [r]	7,350 [r]	7,410
July-December	6,900 [r]	7,060 [r]	6,730
Total	13,900 [r]	14,400 [r]	14,100

[p]Preliminary. [r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Calculated from production plus imports minus exports and industry stock changes.

Source: U.S. Census Bureau.

TABLE 3
MAJOR DOWNSTREAM NITROGEN COMPOUNDS PRODUCED IN THE UNITED STATES[1, 2]

(Thousand metric tons)

	2004						2005[p]					
	January-June[r]		July-December		Total		January-June		July-December		Total	
	Gross weight	Nitrogen content	Gross weight[r]	Nitrogen content	Gross weight	Nitrogen content	Gross weight	Nitrogen content	Gross weight	Nitrogen content	Gross weight	Nitrogen content
Urea	2,760	1,270	3,000	1,380 [r]	5,760	2,640	2,930	1,340	2,270	1,040	5,190	2,380
Ammonium phosphates[e, 3]	7,780	1,220	7,510	1,190	15,300 [r]	2,400	7,500	1,270	7,050	1,160	14,600	2,430
Ammonium nitrate	3,110	1,060	3,450	1,170 [r]	6,560 [r]	2,220 [r]	3,480	1,180	2,880	975	6,350	2,150
Nitric acid	3,260	717	3,210	706 [r]	6,470 [r]	1,420 [r]	3,450	758	2,890	635	6,330	1,390
Ammonium sulfate[4]	1,420	300	1,310	278 [r]	2,730 [r]	578 [r]	1,320	280	1,260	267	2,580	547

[e]Estimated. [p]Preliminary. [r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Ranked in relative order of importance by nitrogen content.
[3]Diammonium phosphate and monoammonium phosphate.
[4]Excludes coke plant ammonium sulfate.

Source: U.S. Census Bureau, Current Industrial Reports MQ325B.

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TABLE 4

DOMESTIC PRODUCERS OF ANHYDROUS AMMONIA IN 2005[1]

(Thousand metric tons per year of ammonia)

Company	Location	Capacity[2]
Agrium Inc.	Borger, TX	490
Do.	Finley, WA[3]	180
Do.	Kenai, AK	1,250
CF Industries Inc.	Donaldsonville, LA	2,040
Coffeyville Resources LLC	Coffeyville, KS	375
Dyno Nobel ASA	Cheyenne, WY	174
Do.	St. Helens, OR	101
Dakota Gasification Co.	Beulah, ND	363
El Dorado Chemical Co.	Cherokee, AL	175
Green Valley Chemical Corp.	Creston, IA	32
Honeywell International Inc.	Hopewell, VA	530
Koch Nitrogen Co.	Beatrice, NE	265
Do.	Dodge City, KS	280
Do.	Enid, OK	930
Do.	Fort Dodge, IA	350
Do.	Sterlington, LA	1,110
Mosaic Co., The	Faustina (Donaldsonville), LA	508
Nitromite Fertilizer (Valero Energy Corp.)	Dumas, TX	128
PCS Nitrogen Inc.	Augusta, GA	688
Do.	Geismar, LA[3]	483
Do.	Lima, OH	542
Royster-Clark Inc.	East Dubuque, IL	278
Shoreline Chemical	Gordon, GA	31
Terra Industries Inc.	Beaumont, TX[3]	231
Do.	Donaldsonville (Ampro), LA[4]	454
Do.	Port Neal, IA	336
Do.	Verdigris, OK	953
Do.	Woodward, OK	399
Do.	Yazoo City, MS	454
Total		14,100

[1]Data are rounded to no more than three significant digits; may not add to total shown.

[2]Engineering design capacity adjusted for 340 days per year of effective production capability.

[3]Idle.

[4]Closed in 2005.

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TABLE 5

U.S. NITROGEN FERTILIZER CONSUMPTION, BY PRODUCT TYPE[1, 2]

(Thousand metric tons of contained nitrogen)

Fertilizer material[3]	2004	2005[P]
Single-nutrient:		
Nitrogen solutions[4]	3,030 [r]	2,870
Anhydrous ammonia	3,050 [r]	2,860
Urea	2,350 [r]	2,170
Ammonium nitrate	470	437
Ammonium sulfate	233	224
Aqua ammonia	98	79
Other[5]	315	315
Total	9,540 [r]	8,950
Multiple-nutrient[6]	2,360 [r]	2,340
Grand total	11,900 [r]	11,300

[P]Preliminary. [r]Revised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Fertilizer years ending June 30.

[3]Ranked in relative order of importance by product type.

[4]Principally urea-ammonium nitrate solutions, 29.9% nitrogen.

[5]Includes other single-nutrient nitrogen materials, all natural organics, and statistical discrepencies.

[6]Various combinations of nitrogen (N), phosphate (P), and potassium (K): N-P-K, N-P, and N-K.

Source: Terry, D.L., and Kirby, B.J., 2006, Commercial fertilizers 2005: Lexington, KY, Association of American Plant Control Officials Inc. and The Fertilizer Institute, 41 p.

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TABLE 6
U.S. PRODUCER STOCKS OF FIXED NITROGEN COMPOUNDS AT END OF PERIOD

(Thousand metric tons of contained nitrogen)

Material[1]	2004	2005[p]
Ammonia:		
January-June	228 [r]	196
July-December	298 [r]	197
Nitrogen solutions:[2]		
January-June	104 [r]	80
July-December	100 [r]	75
Urea:		
January-June	42 [r]	47
July-December	45 [r]	98
Ammonium phosphates:[3]		
January-June	60 [r]	63
July-December	82	76
Ammonium nitrate:		
January-June	27 [r]	36
July-December	47 [r]	52
Ammonium sulfate:		
January-June	21	22
July-December	18	34
Yearend total[4]	590 [r]	532

[p]Preliminary. [r]Revised.
[1]Ranked in relative order of importance.
[2]Urea-ammonium nitrate and ammoniacal solutions.
[3]Diammonium and monoammonium phosphates.
[4]Calendar year ending December 31.

Source: U.S. Census Bureau, Current Industrial Reports MQ325B.

TABLE 7
PRICE QUOTATIONS FOR MAJOR NITROGEN COMPOUNDS AT END OF PERIOD

(Dollars per short ton)

	2004		2005	
Compound	June	December	June	December
Ammonium nitrate, free on board (f.o.b.) Corn Belt[1]	178-190	195-210	225	265-270
Ammonium sulfate, f.o.b. Corn Belt[1]	165-175	180-190	210-218	195-200
Anhydrous ammonia:				
F.o.b. Corn Belt[1]	295-315	350-370	335-375	475-490
F.o.b. Gulf Coast[2]	270	285	305	360
Diammonium phosphate, f.o.b. central Florida	180-185	205-215	210-213	230-233
Urea:				
F.o.b. Corn Belt,[1] prilled and granular	198-208	255-270	285-300	300-325
F.o.b. Gulf Coast, granular[2]	187-188	225-230	250-255	260-267

[1]Illinois, Indiana, Iowa, Missouri, Nebraska, and Ohio.
[2]Barge, New Orleans, LA.

Source: Green Markets.

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TABLE 8
U.S. EXPORTS OF ANHYDROUS AMMONIA, BY COUNTRY[1]

(Thousand metric tons of ammonia)

Country	2004	2005
Canada	10	10
Chile	15	17
China	--	38
Korea, Republic of	383	552
Mexico	16	10
Philippines	24	--
Taiwan	10	8
Other	5	4
Total	463	639

-- Zero.

[1]Value data suppressed by U.S. Census Bureau.

Source: U.S. Census Bureau.

TABLE 9
U.S. IMPORTS OF ANHYDROUS AMMONIA, BY COUNTRY[1]

(Thousand metric tons of ammonia and thousand dollars)

	2004		2005	
Country	Gross weight	Value[2]	Gross weight	Value[2]
Canada	1,280	323,000	1,340	451,000
Indonesia	67	16,900	22	9,120
Latvia	(3)	8,640	118	33,500
Russia	864	212,000	426	136,000
Trinidad and Tobago	3,880	1,030,000	4,490	1,370,000
Ukraine	524	138,000	1,160	349,000
Venezuela	323	87,300	148	44,800
Other	236	66,100	222	66,800
Total	7,180	1,880,000	7,930	2,460,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Cost, insurance, and freight value.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 10
U.S. EXPORTS OF MAJOR NITROGEN COMPOUNDS[1]

(Thousand metric tons)

Compound	2004 Gross weight	2004 Nitrogen content	2005 Gross weight	2005 Nitrogen content	Principal destinations, 2005
Ammonium nitrate[2]	109	37	82	28	Mexico, 64%; Canada, 26%.
Ammonium sulfate[2]	718	194	665	180	Brazil, 41%; Guatemala, 11%; Canada, 10%.
Anhydrous ammonia	463	381	639	525	Republic of Korea, 86%.
Diammonium phosphate	5,040	907	5,620	1,010	China, 24%; India, 21%; Pakistan, 11%.
Monoammonium phosphate	3,420	376	2,890	318	Australia, 22%; Canada, 21%; Brazil, 18%.
Urea	704	323	536	246	Mexico, 59%; Republic of Korea, 25%.
Total	10,500	2,220	10,400	2,310	

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes industrial chemical products.

Source: U.S. Census Bureau.

TABLE 11
U.S. IMPORTS OF MAJOR NITROGEN COMPOUNDS[1]

(Thousand metric tons and thousand dollars)

Compound	2004 Gross weight	2004 Nitrogen content	2004 Value[2]	2005 Gross weight	2005 Nitrogen content	2005 Value[2]	Principal sources, 2005
Ammonium nitrate[3]	1,060	358	191,000	886	300	189,000	Canada, 61%; Romania, 15%.
Ammonium nitrate-limestone mixtures	2	1	178	2	1	209	Japan, 61%; Netherlands, 27%.
Ammonium sulfate[3]	326	69	37,500	280	59	45,200	Canada, 98%.
Anhydrous ammonia[4]	7,180	5,900	1,880,000	7,930	6,520	2,220,000	Trinidad and Tobago, 57%; Canada, 17%; Ukraine, 15%.
Calcium nitrate	126	21	11,100	119	20	13,100	Norway, 88%; Ukraine, 11%.
Diammonium phosphate	31	6	12,900	10	2	9,130	Mexico, 59%; China, 21%.
Monoammonium phosphate	156	17	48,600	141	16	56,400	Canada, 75%; Mexico, 9%.
Nitrogen solutions	2,010	602	319,000	2,820	844	543,000	Romania, 26%; Russia, 22%; Canada, 15%.
Potassium nitrate	66	9	21,800	87	12	33,900	Chile, 56%; Israel, 39%.
Potassium nitrate-sodium nitrate mixtures	42	6	14,800	6	1	2,250	Israel, 68%; Canada, 30%.
Sodium nitrate	66	11	15,700	71	12	20,000	Chile, 93%.
Urea	4,940	2,270	1,020,000	5,670	2,600	1,540,000	Canada, 31%; Qatar, 13%; Saudi Arabia, 9%.
Total	16,000	9,270	3,580,000	18,000	10,400	4,670,000	

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Cost, insurance, and freight value.
[3]Includes industrial chemical products.
[4]Includes industrial ammonia.

Source: U.S. Census Bureau.

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TABLE 12
AMMONIA: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons of contained nitrogen)

Country	2001	2002	2003	2004	2005[e]
Afghanistan[e]	20	20	20	20	20
Albania[e]	10	10	10	10	10
Algeria	469	563	578	543 [r]	550
Argentina	597	617	724	701	580
Australia	762	686	787	790	790
Austria[e]	440	440	440	440	440
Bahrain	372	377	312	311	312
Bangladesh[3]	1,273	1,289	1,389	1,380	1,380
Belarus	725	799	726	765 [e]	800 [4]
Belgium	788	842	874	857	860
Bosnia and Herzegovina[e]	1	1	1	1	1
Brazil	769	1,021	939	1,077	1,070
Bulgaria	477	328	321	389	390
Burma	28	21	63	35 [e]	35
Canada	3,439	3,700	3,662	4,107	4,000
China	28,200	30,200	31,500	34,800 [e]	37,800 [p]
Colombia	95	111	108	98	100
Croatia	259	235	264	332	330
Cuba[e]	135	135	135	135	135
Czech Republic	206	215	235	233	233
Denmark[e]	2	2	2	2	2
Egypt	1,801	1,839	1,790	1,675	1,640
Estonia	151	39	81	166	170
Finland[e]	80	87	77 [r]	61 [r]	63
France	1,380 [e]	1,172	1,153	1,120	1,150
Georgia	60	90	125	130 [e]	130
Germany	2,522	2,623	2,803	2,741	2,700
Greece	57	66	123	132	130
Hungary	324	238	232	304	300
Iceland	3	--	--	--	--
India[5]	10,081	9,827	10,048	10,718	10,800
Indonesia	3,655	4,200	4,250	4,120	4,400
Iran	1,087	1,119	1,115	1,088	1,020
Iraq[e]	280	532	--	30 [r]	30
Ireland[e]	443 [4]	400	--	--	--
Italy	434	391	475	532	500
Japan	1,318	1,192 [r]	1,061 [r]	1,101 [r]	1,083 [4]
Korea, North[e]	100	100 [r]	100 [r]	100 [r]	100
Korea, Republic of	385 [r]	153	119	163	150
Kuwait	400	414	444	413	440
Libya	495	533	577 [e]	577 [e]	580
Lithuania	444 [r]	468 [r]	462 [r]	424	430
Malaysia	726	848	910	843	920
Mexico	548	437	440	568	440
Netherlands	1,989	2,053	1,750 [e]	1,970 [e]	1,700
New Zealand	117	109	128	124	120
Norway	323	330	354	420	450
Oman	--	--	--	--	706
Pakistan	2,228	2,214	2,357	2,114	2,110
Peru[e]	5	5	5	5	5
Poland	1,735	1,311	1,906	1,976	2,000
Portugal	202	190	245	244	245
Qatar	1,159	1,166	1,185	1,428	1,700
Romania	949	930	1,180	1,172	1,200

See footnotes at end of table.

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TABLE 12—Continued
AMMONIA: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons of contained nitrogen)

Country	2001	2002	2003	2004	2005[e]
Russia	8,690	8,600 [e]	9,100 [e]	9,800	10,000
Saudi Arabia	1,774	1,737	1,743	1,726	1,780
Serbia and Montenegro	66	115	62	136	135
Slovakia	215	226	230	268	270
South Africa	506	492	493	459	460
Spain	436	415	432	404	460
Switzerland	31	33	29	32	32
Syria	138	143	161	115	120
Taiwan	12	11	11	11 [e]	11
Tajikistan[e]	5	15	20	20	20
Trinidad and Tobago	3,036	3,296	3,529	3,875	4,200
Turkey	67	301	289	329	330
Turkmenistan[e]	75	85	85	85	85
Ukraine	3,700	3,700	3,900 [e]	3,900 [e]	4,300
United Arab Emirates	358	364	421	380	360
United Kingdom	850	837	1,044	1,071	1,080
United States[6]	9,120	10,300	8,450 [r]	8,990 [r]	8,040 [p]
Uzbekistan	670	740	815 [e]	840 [e]	850
Venezuela	808	666	732	1,012	900
Vietnam	53	58	80 [e]	216	220
Zimbabwe[e]	58	61	55	48	30
Total	105,000	109,000	110,000	117,000	121,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data have been rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 18, 2006.

[3]May include nitrogen content of urea.

[4]Reported figure.

[5]Data are for years beginning April 1 of that stated.

[6]Synthetic anhydrous ammonia; excludes coke oven byproduct ammonia.

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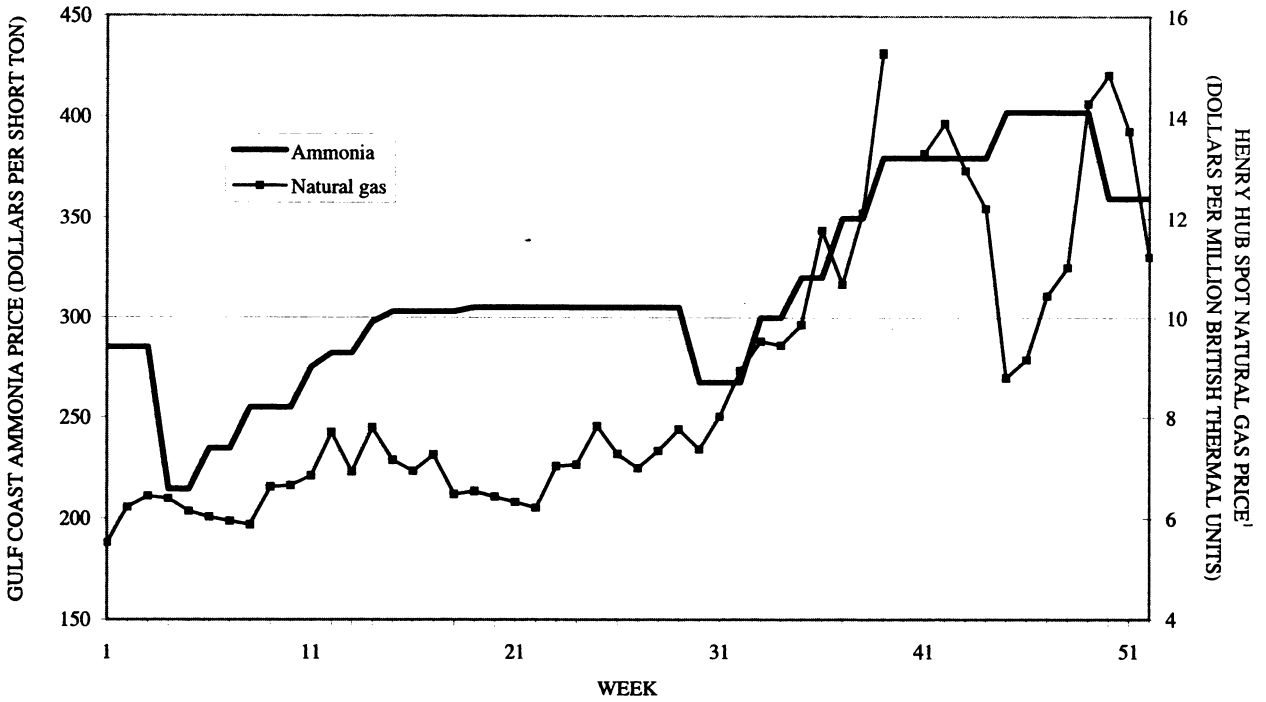
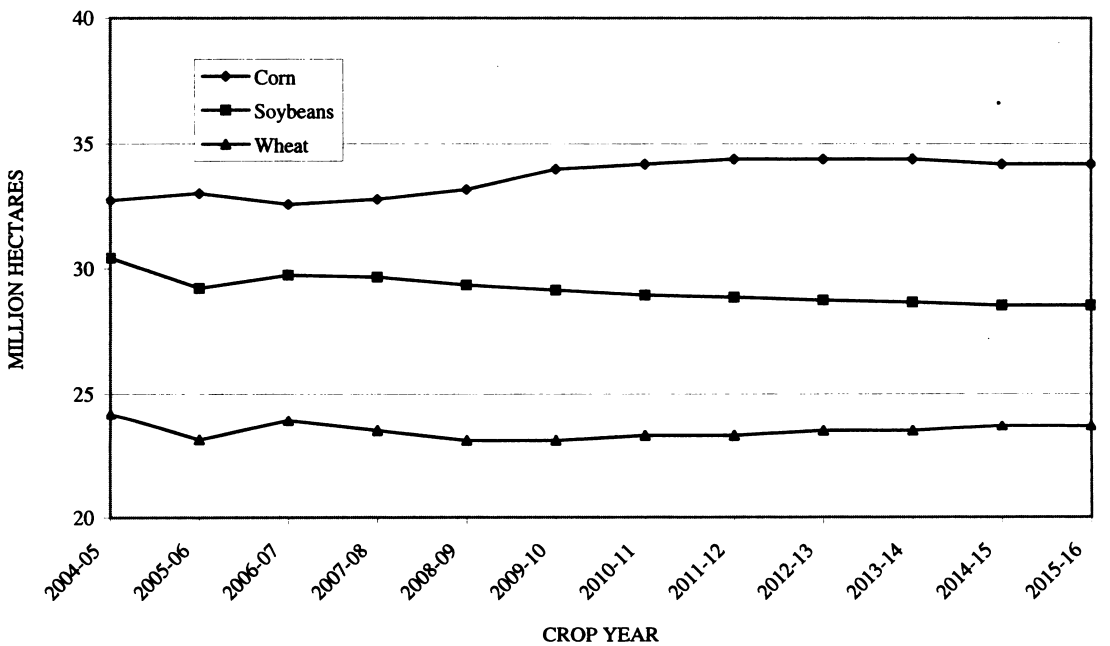
FIGURE 1
AMMONIA AND NATURAL GAS PRICES IN 2005



[1]Trading on Henry Hub was suspended from September 23 to October 6.

Sources: Green Markets and Natural Gas Weekly.

FIGURE 2
PROJECTED PLANTED ACREAGE



Source: U.S. Department of Agriculture.

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PEAT

By Stephen M. Jasinski

Domestic survey data and tables were prepared by Jeffrey A. Milanovich, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Peat production in the conterminous United States in 2005 was 685,000 metric tons (t), a slight decrease from that of 2004 (table 1). Output from Alaska was 45,900 cubic meters, according to the Alaska Department of Natural Resources, which conducted its own survey of mineral production in the State (Szumigala and Hughes, 2006, p. 15). Production in Alaska was reported by volume only.

The United States is a significant producer and consumer of peat for horticultural and industrial purposes. The types of peat are classified according to the degree of composition of component plant material with sphagnum moss being the least decomposed, followed by hypnum moss, reed-sedge, and humus.

Reed-sedge accounted for 88% of domestic peat production, followed by sphagnum moss, 5%; humus, 4%; and hypnum moss, 3% (table 4). Florida, Michigan, and Minnesota accounted for 87% of U.S. production (table 3). Florida was the leading producer with 436,000 t.

Peat is a renewable natural organic material of botanical origin and commercial significance. Peatlands are situated in wetland areas, primarily in the temperate and cold belt of the Northern Hemisphere where large deposits developed from the gradual decomposition of plant matter under anaerobic conditions. The United States contains approximately 15% of the world's peatlands by area (Lappalainen, 1996, p. 55). More than 400 million hectares (Mha) of peatlands exists on Earth, of which 80% remains undisturbed. Of the 80 Mha that has been used by humans, 50% has been used for agriculture; 30%, for forestry; 10%, for miscellaneous uses; and 10%, for peat extraction. Peat continues to accumulate on 60% of global peatlands; however; the volume of global peat resources has been decreasing at a rate of 0.05% per year owing to human activity (Joosten and Clarke, 2002).

Production

Domestic production data for peat were developed by the U.S. Geological Survey from a voluntary canvass of operations in the conterminous United States (tables 1, 2). Of the 69 operations to which a survey request was sent, 58 responded, representing about 75% of total production tonnage. There were 45 active operations, and 13 companies reported no activity in 2005. Data for nonrespondents were estimated based on responses to the 2004 survey or other sources.

Consumption

Sales of domestic peat increased slightly to 751,000 t from 741,000 t in 2004. Packaged products composed 28% of total domestic sales tonnage and commanded premium prices for all grades of peat. Apparent consumption increased by 15% compared with that of 2004 owing to higher imports of peat and a reduction in stocks. Potting soil and general soil improvement mixes were the two leading usage categories, accounting for 93% of domestic sales tonnage and volume (table 5). Other significant uses included golf course applications, mixed fertilizers, nursery applications, and seed inoculants. The United States imported 57% of total consumption requirements, primarily from Canada where deposits of high-quality sphagnum moss are extensive. Canadian peat was sold in bulk for blending in custom soil mixes and was packaged for horticultural use; however, a detailed distribution of uses was not available.

Peat has widespread use as a plant-growth medium in a variety of agricultural and horticultural applications where its fibrous structure and porosity promote a unique combination of water-retention and drainage characteristics. Commercial applications include lawn and garden soil amendments, potting soils, and turf maintenance on golf courses. In industry, peat is used primarily as a filtration medium to remove toxic materials from process waste streams, pathogens from sewage effluents, and deleterious materials suspended in municipal storm-drain water. In its dehydrated form, peat is a highly effective absorbent for fuel and oil spills on land and water.

Stocks

U.S. yearend stocks of peat decreased to 195,000 t from 251,000 t in 2004 (table 1). Reed-sedge peat accounted for 77% of total stocks, followed by hypnum moss, humus, and sphagnum moss (table 4).

Prices

The total reported free on board (f.o.b.) value for domestic peat sold in the United States was $20.8 million, according to the annual survey of domestic peat producers. The average unit value decreased to $27.76 per metric ton compared with $28.64 per ton in 2004 (table 1). On an average unit-value basis, sphagnum moss was valued at $70.84 per ton, f.o.b. plant; hypnum moss, $44.36 per ton; reed-sedge, $23.84 per ton; and humus, $18.34 per ton (table 7).

Foreign Trade

Imports of peat increased by 13% to 891,000 t from 786,000 t in 2004 (table 8). The total customs import value was $195 million or $219.14 per ton. Imports of sphagnum moss from Canada increased to 876,000 t, which represented 98% of total U.S. imports and 66% of total Canadian production. U.S. companies exported 36,000 t of peat.

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World Review

Finland, Ireland, Russia, Belarus, Canada, and Ukraine were the leading producer countries in decreasing order of tonnage (table 9). Other significant producing countries included Estonia, Latvia, Sweden, and the United States. Peat is an important source of energy in Finland and Ireland and to a lesser extent in Eastern Europe.

Canada.—Production of sphagnum moss decreased to 1.33 million metric tons (Mt) from 1.35 Mt in 2004. New Brunswick, Quebec, and Alberta were the major producing provinces, in decreasing order of tonnage, accounting for 82% of production. British Columbia, Manitoba, Newfoundland, Nova Scotia, Prince Edward Island, and Saskatchewan also reported peat production (Natural Resources Canada, 2006§[1]). Exports to the United States increased to 876,000 t compared with 773,000 t in 2004.

Outlook

Peat consumption is likely to increase owing to strong demand in the horticultural industry. Domestic peat production is likely to remain level in the near term, however, and the shortfall will probably be filled by increased imports from Canada; sphagnum peat from Canada is preferred for custom soil blending and retail sales. Other factors, such as competition from organic soil amendments like coir (coconut fiber) and composted yard waste, Federal and State wetlands regulations, and restrictions on permitting new production sites, will likely have a depressing effect on domestic peat production.

[1]A reference that includes a section mark (§) is found in the Internet References Cited section.

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TABLE 1
SALIENT PEAT STATISTICS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

	2001	2002	2003	2004	2005
United States:[2]					
Number of active operations	57	55	54	50	45
Production	736	642	634	696	685
Sales by producers:					
Quantity:					
Bulk	500	515	447	550	537
Packaged	320	213	185	191	214
Total	820	728	632	741	751
Value	21,100	21,000	18,800	21,200	20,800
Average value dollars per metric ton	25.75	28.85	29.74	28.64	27.76
Average value, bulk do.	22.91	22.74	22.60	22.88	23.08
Average value, packaged or baled do.	30.18	43.61	46.98	45.20	39.54
Exports	31	32	29	29	36
Imports for consumption	776	763	767	786	891
Consumption, apparent[3]	1,500	1,420	1,400	1,380	1,600
Stocks, December 31, producers'	257	207	180	251	195
World, production	23,200 r	26,200 r	25,200 r	26,400 r	26,400 e

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits, except average values per metric ton.

[2]Excludes Alaska.

[3]Apparent consumption equals U.S. production plus imports minus exports plus adjustments for industry stock changes.

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TABLE 2
RELATIVE SIZE OF PEAT OPERATIONS IN THE UNITED STATES

Size	Active operations		Production (thousand metric tons)	
(metric tons per year)	2004	2005	2004	2005
23,000 and more	7	7	553	551
9,000 to 22,999	3	5	38	52
5,000 to 8,999	11	8	75	48
1,000 to 4,999	11	9	23	27
Less than 1,000	18	16	7	8
Total	50	45	696	685

TABLE 3
U.S. PEAT PRODUCTION AND SALES BY PRODUCERS IN 2005, BY STATE[1]

Region and State	Active operations	Production (thousand metric tons)	Sales Quantity (thousand metric tons)	Sales Value[2] (thousands)	Sales Percentage packaged
East:					
Florida	7	436	464	$9,450	1
Pennsylvania	5	7	7	210	75
Other[3]	6	21	22	998	42
Total or average	18	464	493	10,700	4
Great Lakes:					
Michigan	5	117	117	3,300	84
Minnesota	10	43	68	5,670	65
Other[4]	7	52	64	914	85
Total or average	22	212	248	9,890	79
West[5]	5	8	9	298	6
Grand total or average	45	685	751	20,800	28

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Values for free on board producing plant.
[3]Includes Maine, New Jersey, New York, and West Virginia.
[4]Includes Illinois, Indiana, and Ohio.
[5]Includes Iowa, Montana, Washington, and Wisconsin.

TABLE 4
U.S. PEAT PRODUCTION AND PRODUCERS' YEAREND STOCKS IN 2005, BY TYPE

Type	Active operations	Production[1] (metric tons)	Percentage of production	Yearend stocks[1] (metric tons)
Sphagnum moss	9	32,500	5	5,800
Hypnum moss	5	22,700	3	28,900
Reed-sedge	21	605,000	88	151,000
Humus	10	25,400	4	10,200
Total	45 [2]	685,000	100	195,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Some plants produce multiple types of peat; may not add to totals shown.

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TABLE 5
U.S. PEAT SALES BY PRODUCERS IN 2005, BY TYPE AND USE[1]

Use	Sphagnum moss Quantity Weight (metric tons)	Sphagnum moss Quantity Volume[2] (cubic meters)	Sphagnum moss Value (thousands)	Hypnum moss Quantity Weight (metric tons)	Hypnum moss Quantity Volume (cubic meters)	Hypnum moss Value (thousands)	Reed-sedge Quantity Weight (metric tons)	Reed-sedge Quantity Volume (cubic meters)	Reed-sedge Value (thousands)
Earthworm culture medium	91	612	$8	--	--	--	321	474	$6
General soil improvement	45,100	297,000	3,060	7,830	15,100	$510	177,000	329,000	3,880
Golf courses	6,900	33,100	586	72	101	2	13,900	37,000	2,300
Ingredient for potting soils	2,640	10,600	214	13,600	22,900	450	441,000	707,000	8,800
Mixed fertilizers	--	--	--	--	--	--	--	--	--
Nurseries	742	3,520	58	576	994	21	7,870	24,300	347
Packing flowers, plants, shrubs, etc.	249	1,680	22	408	765	16	--	--	--
Seed inoculant	--	--	--	--	--	--	6,400	12,200	90
Vegetable growing	58	98	2	54	76	1	91	153	5
Other	--	--	--	--	--	--	--	--	--
Total	55,800	347,000	3,950	22,500	40,000	1,000	647,000	1,110,000	15,400

Use	Humus Quantity Weight (metric tons)	Humus Quantity Volume (cubic meters)	Humus Value (thousands)	Total Quantity Weight (metric tons)	Total Quantity Volume (cubic meters)	Total Value (thousands)
Earthworm culture medium	966	1,610	$17	1,380	2,700	$31
General soil improvement	5,460	8,070	84	236,000	650,000	7,530
Golf courses	227	321	2	21,100	70,600	2,890
Ingredient for potting soils	2,020	2,450	36	460,000	743,000	9,500
Mixed fertilizers	852	1,030	21	852	1,030	21
Nurseries	8,070	11,700	173	17,200	40,500	599
Packing flowers, plants, shrubs, etc.	667	826	8	1,320	3,270	46
Seed inoculant	395	443	6	6,790	12,700	96
Vegetable growing	422	489	7	625	817	15
Other	6,330	7,620	112	6,330	7,620	112
Total	25,400	34,600	466	751,000	1,530,000	20,800

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Volume of nearly all sphagnum moss was measured after compaction and packaging.

TABLE 6
AVERAGE DENSITY OF DOMESTIC PEAT SOLD IN 2005

(Kilograms per cubic meter)[1]

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus
Bulk	218	606	601	751
Packaged	144	480	531	723
Bulk and packaged	161	564	583	735

[1]To convert kilograms per cubic meter to pounds per cubic yard multiply by 1.685.

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TABLE 7
PRICES FOR PEAT IN 2005[1]

(Dollars per unit)

	Sphagnum moss	Hypnum moss	Reed-sedge	Humus	Average
Domestic:					
Bulk:					
Per metric ton	68.82	32.31	21.31	18.19	23.08
Per cubic meter	14.98	19.59	12.81	13.66	13.19
Packaged or baled:					
Per metric ton	71.73	74.63	31.95	18.45	39.54
Per cubic meter	10.36	35.80	16.96	13.34	14.27
Average:					
Per metric ton	70.84	44.36	23.84	18.34	27.76
Per cubic meter	11.40	25.01	13.89	13.47	13.61
Imported, total, per metric ton[2]	XX	XX	XX	XX	219.14

XX Not applicable.
[1]Prices are free on board plant.
[2]Average customs value.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF PEAT MOSS, BY COUNTRY[1]

	2004		2005	
Country	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Canada	773,000	$155,000	876,000	$191,000
Denmark	1,650	379	176	71
Finland	374	110	450	155
France	500	26	--	--
Germany	320	99	357	106
Ireland	3,940	274	4,260	306
Latvia	5,580	1,980	9,150	3,300
Netherlands	136	79	96	64
United Kingdom	184	110	37	30
Other	212	177	100	160
Total	786,000	159,000	891,000	195,000

--Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Customs value.

Source: U.S. Census Bureau.

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TABLE 9
PEAT: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	2001	2002	2003[e]	2004[e]	2005[e]
Argentina, horticultural use	10	8	9 [4]	111 [r, 4]	100
Australia[e]	5	5	5	6	6
Belarus:[e]					
Horticultural use	100	100	100	100	100
Fuel use	2,000	2,201 [4]	1,802 [4]	1,800	1,800
Total	2,100	2,301 [4]	1,902 [4]	1,900	1,900
Burundi, fuel use	7	7	5	5 [4]	5
Canada, horticultural use	1,319	1,385	1,341 [4]	1,347 [r, 4]	1,325 [4]
Denmark, horticultural use[e]	287	290	295	296	298
Estonia, horticultural use and fuel use	844	1,508	1,012 [4]	764 [r, 4]	800
Finland:					
Horticultural use	834	759 [r]	929 [r, 4]	905 [r, 4]	900
Fuel use	5,368	6,515 [r]	8,415 [r, 4]	8,159 [r, 4]	8,200
Total	6,202	7,274 [r]	9,344 [r, 4]	9,064 [r, 4]	9,100
France, horticultural use[e]	200	200	200	200	200
Germany, horticultral use	115 [r]	123 [r]	135 [r, 4]	120 [r, 4]	120
Hungary, horticultural use[e]	45	45	45	45	45
Ireland:[5]					
Horticultural use[e]	300	350	451 [4]	400	400
Fuel use	4,599	4,138	2,739 [4]	5,200	5,000
Total	4,899	4,488	3,190 [4]	5,600	5,400
Latvia, horticultural use and fuel use	555	1,485	1,076 [4]	689 [r, 4]	800
Lithuania, horticultural use and fuel use	273	513	367 [4]	369 [r, 4]	370
Moldova, fuel use[e]	475	475	475	475	475
New Zealand, horticultural use[e]	24	24	24	25	25
Norway, horticultural use[e]	30	30	30	30	30
Poland, horticultural use	325	316	431 [r, 4]	400 [r]	400
Russia, horticultural use and fuel use	2,100	2,100	2,100	2,100	2,100
Spain[e]	50	50	50	50	50
Sweden:[e]					
Horticultural use	400	540	540	330	360
Fuel use	700	850	790	560	570
Total	1,100	1,390	1,330	890	930
Ukraine, horticultural use and fuel use[e]	1,000	1,000	1,000	1,000	1,000
United Kingdom[e]	500	500	250	250	250
United States, horticultural use	736	642	634 [4]	696 [4]	685 [4]
Grand total	23,200 [r]	26,200 [r]	25,200 [r]	26,400 [r]	26,400
Of which:					
Horticultural use	4,730 [r]	4,820 [r]	5,160 [r]	5,000 [r]	4,990
Fuel use	13,100	14,200 [r]	14,200 [r]	16,200 [r]	16,000
Unspecified	5,330	7,160	5,860	5,230 [r]	5,380

[e]Estimated. [r]Revised.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 25, 2006.

[3]In adddition to the countries listed, Austria, Chile, Iceland, Italy, and Romania produced negligible amounts of peat.

[4]Reported figure.

[5]Fiscal year data.

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PERLITE

By Wallace P. Bolen

Domestic survey data and tables were prepared by Virginia C. Harper, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

In 2005, the amount of domestic processed crude sold or used was essentially equal with that of 2004. The amount of expanded perlite sold or used increased slightly. Domestic production of processed crude perlite was about 508,000 metric tons (t), and the amount of expanded perlite sold or used was about 677,000 t. Imports of crude processed perlite decreased by about 18% to 196,000 t, the lowest level of imports since 2001. Exports of crude processed perlite were estimated to have been about 32,000 t, down by about 14% compared with those of 2004. Trade data in this report are from the U.S. Census Bureau. Percentages in this report were computed using unrounded data.

Production

According to the data collected by the U.S. Geological Survey (USGS), the 508,000 t of U.S.-processed crude perlite sold or used in 2005 was valued at $20.7 million, a slight increase compared with that of 2004. The 677,000 t of expanded perlite sold or used by domestic producers was valued at $165 million, an increase of about 9.3% compared with that of 2004 (table 1).

Domestic production data for perlite were derived by the USGS from two voluntary annual surveys—one for domestic mine operations (processed crude perlite) and one for expanding plants. The expanding plants used domestic and imported processed crude perlite. All the processed crude perlite described in table 1 was produced at 10 mines operated by 7 companies; 6 of the 10 mines responded to the USGS survey, representing about 87% of the processed crude perlite sold or used in 2005. The processed crude perlite that is reported in table 1 was mined in Arizona, California, Idaho, Nevada, New Mexico, Oregon, and Utah. The mines in New Mexico and Oregon accounted for most of the tonnage mined. Ore producers, in alphabetical order by State, were Harborlite Corp. in Arizona, New Mexico, and Utah; American Perlite Co. in California; Idaho Minerals LLC in Idaho; Eagle-Picher Minerals, Inc. and Wilkins Mining and Trucking, Inc. in Nevada; Dicaperl Corp. in New Mexico; and Cornerstone Industrial Minerals Corp. in Oregon.

All of the 62 expanding plants canvassed were active. Of those, 36 plant operators (58%) responded, reporting about 70% of the total expanded perlite sold or used. Production information for nonresponding companies was estimated based on previously reported data. The top seven producers of expanded perlite, each with production of more than 25,000 metric tons per year, accounted for about 82% of expanded perlite sold or used in the United States in 2005. The remaining 18% was produced by 25 companies.

The information in the 2004 perlite report contained incorrect information regarding Noble Materials Inc. In September 2004, Noble Materials with plants in Fallon, NV, and Oklahoma City, OK, sold its assets to the parent company of Grefco Minerals, Inc. Noble Acquisitions LLC is the immediate legal controlling company and is not affiliated with Grefco Minerals. The plants will be operated under the name Noble Perlite.

World Minerals, Inc. (the parent of Harborlite Corp.) purchased the crude perlite processing plant and the expanding plant of Basin Perlite near Milford, UT. However, Harborlite did not purchase the perlite mine but opted to open a new mine in the vicinity. Subsequent to this action, World Minerals was purchased by the French company Imerys, SA in July. Imerys is a global company active in many different mining and mineral product sectors. Imerys emphasized the value of World Minerals' filtration applications, both perlite and diatomite, in their annual report for 2005.

In December, Compagnie de Saint-Gobain, a French building materials supplier, purchased British building material supplier BPB plc. Since 2000, BPB has been the parent company of Celotex Corporation, one of the top producers and consumers of expanded perlite in the United States.

A new producer, A&B Industrial Services of Sulphur, LA, reported the expansion and sale of perlite. The company was expected to initially be producing expanded perlite mostly for low-temperature uses in the Gulf Coast oil and gas sector.

Consumption

In 2005, domestic apparent consumption of processed crude perlite was 672,000, a 5.2% decrease compared with that of 2004. Expanded perlite consumed for construction-related uses, the major market for expanded material, was about 417,000 t, a slight increase compared with that of 2004. Construction uses of expanded perlite, which consisted of concrete aggregate, formed products, masonry- and cavity-fill insulation, and plaster aggregate, accounted for about 61% of total domestic sales in 2005. Expanded perlite consumption increased for fillers, filter aid, formed products, horticultural aggregates, low-temperature insulation, masonry- and cavity-fill insulation, and plaster aggregate, while consumption decreased for concrete aggregate, laundries, and other miscellaneous uses (table 3). Perlite was expanded, usually for local consumption, in 31 States. The leading States in production of expanded perlite sold or used, in descending order, were Illinois, Georgia, Mississippi, Pennsylvania, Minnesota, Virginia, Alabama, California, Oregon, and Florida. The amount of expanded perlite sold or used by State is available for those States with three or more companies expanding in each State; other States are not published to avoid disclosing proprietary data (table 2).

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Prices

Processed crude perlite was sold at an average value of $40.56 per metric ton, which was a slight decrease compared with that of 2004. Perlite consumed by expanding plants operated by the mining companies was valued at $40.75 per ton, which was a increase of about 4.2% compared with that of 2004. The average price for all perlite sold or used by mining companies was $40.68 per ton, which was a slight decrease compared with that of 2004. The average price of expanded perlite was $243 per ton, up from $226 per ton in 2004; the range in reported prices, however, was wide—from less than $100 per ton to more than $1,000 per ton.

The average price by use of expanded perlite, in descending order, was low-temperature insulation, $464 per ton; plaster aggregate, $461 per ton; fillers, $426 per ton; masonry- and cavity-fill insulation, $347 per ton; filter aid, $342 per ton; concrete aggregate, $334 per ton; horticultural aggregate, $324 per ton; laundries, $269 per ton; and formed products, $161 per ton (table 3).

Foreign Trade

Export and import data were derived from U.S. Census Bureau data. Exports of processed crude and expanded perlite, primarily to Canada, were estimated to be 32,000 t, down by 14% compared with those of 2004. The value of exports could not be calculated based on available information, but the average prices quoted previously could be applied.

Imports of processed crude perlite, almost exclusively from Greece, decreased by 18% to about 196,000 t compared with those of 2004. The average customs value of perlite imports was estimated to be $34.60 per ton. If insurance and freight costs ($5.00) were added to the value of the imports, the total average value of imports was estimated to rise to $39.60 per ton, an increase of 14% compared with the average value in 2004.

Perlite expanding plants, mostly in the Eastern United States, continued to purchase less expensive, imported perlite. Imported perlite has a price advantage compared with domestically produced perlite owing to the low cost of shipping it from Greece to the United States east coast versus higher domestic rail transportation costs. Perlite production in Greece is centered on the islands of Milos and Kos, which offer deepwater access to large ocean-going vessels, thus lowering freight cost. U.S. producers normally must transport perlite by rail, which is subject to higher insurance and freight rates, resulting in higher transportation cost per ton than waterborne transport.

World Industry Structure

Based on available information, the United States was estimated to be the leading consumer of processed crude and expanded perlite in 2005. Greece was estimated to have produced about 525,000 t and sold or used the largest amount of perlite among the countries listed in table 4. Other leading producers of processed crude perlite, in descending order, were the United States, Japan, Mexico, Hungary, and Turkey. In 2005, 15 countries produced 1.95 million metric tons of perlite. Owing to a lack of reliable information, however, this total does not include all major producing countries, such as China, which was probably the first or second ranked producer in the world.

Outlook

Total consumption of processed and expanded perlite in the United States was expected to remain near 2005 levels in 2006. Recent large jumps in energy cost were expected to have a negative impact on the rate of perlite consumption. Perlite imports were expected to rebound slightly from the 4-year low in 2005. Prices for processed crude and especially expanded perlite were expected to increase because costs for transportation (waterborne and rail) and the expansion process were expected to rise owing to sustained increases in fuel costs.

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TABLE 1

PERLITE MINED, PROCESSED, AND EXPANDED IN THE UNITED STATES[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

		2001	2002	2003	2004	2005
Perlite mined[2]		611	638	591	601	606
Processed perlite:						
Sold to expanders:						
Quantity		490	419	381	407	406
Value		17,900	15,100	14,800	16,700	16,500
Average value	dollars per ton	36.52	36.01	38.76	40.93	40.56
Used at own plants to make expanded perlite:						
Quantity		97	102	112	101	103
Value		3,450	3,890	4,060	3,950	4,200
Average value	dollars per ton	35.52	38.13	36.89	39.10	40.75
Total, sold and used:						
Quantity		588	521	493	508	508
Value		21,300	19,000	18,800	20,600	20,700
Average value	dollars per ton	36.29	36.42	38.20	41.81	40.68
Expanded perlite:						
Production, quantity		686	674	665	673	677
Sold or used:						
Quantity		693	672	664	670	677
Value		146,000	146,000	147,000	151,000	165,000
Average value	dollars per ton	211.24	217.84	221.38	225.98	243.07

[1]Data are rounded to no more than three significant digits, except average value; may not add to totals shown.

[2]Crude ore mined and stockpiled for processing.

TABLE 2

EXPANDED PERLITE PRODUCED AND SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

	2004				2005			
		Sold or used				Sold or used		
State	Production, quantity (metric tons)	Quantity (metric tons)	Value (thousands)	Average value[2] (dollars per metric ton)	Production, quantity (metric tons)	Quantity (metric tons)	Value (thousands)	Average value[2] (dollars per metric ton)
California	31,500	31,500	$10,500	334	34,200	34,200	$11,200	327
Florida	34,000	30,700	7,770	253	31,400	31,400	8,280	263
Michigan	21,000	21,000	5,380	256	21,600	21,600	5,910	273
Mississippi	64,400	64,400	8,990	139	61,000	61,000	9,630	157
Nevada	3,820	3,820	1,120	292	6,610	6,610	3,950	596
Pennsylvania	52,200	52,200	9,260	177	51,900	51,900	9,920	191
Other[3]	466,000	466,000	108,000	223	470,000	470,000	116,000	246
Total or average	673,000	670,000	151,000	226	677,000	677,000	165,000	243

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Average value is based on unrounded data and rounded to the nearest dollar.

[3]Includes Alabama, Arizona, Arkansas, Colorado, Georgia, Idaho, Illinois, Indiana, Louisiana (2005), Kansas, Maine, Massachusetts, Minnesota, Missouri, Nevada, New Jersey, North Carolina, Ohio, Oklahoma, Oregon, Tennessee, Texas, Utah, Virginia, Wisconsin, and Wyoming.

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TABLE 3

EXPANDED PERLITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE[1]

Use	2004 Quantity (metric tons)	2004 Value (thousands)	2004 Average value[2] (dollars per metric ton)	2005 Quantity (metric tons)	2005 Value (thousands)	2005 Average value[2] (dollars per metric ton)
Concrete aggregate	2,790	$1,090	389	2,140	$715	334
Fillers	74,000	29,300	395	77,400	32,900	426
Filter aid	49,600	16,300	328	50,600	17,300	342
Formed products[3]	398,000	58,400	147	399,000	64,100	161
Horticultural aggregate	90,800	29,400	324	95,300	30,900	324
Laundries	3,170	855	270	1,060	284	269
Low-temperature insulation	1,790	799	448	1,810	838	464
Masonry- and cavity-fill insulation	3,310	1,130	342	4,060	1,410	347
Plaster aggregate	11,500	3,780	328	11,600	5,350	461
Other[4]	35,600	10,400	293	34,700	10,700	308
Total or average	670,000	151,000	226	677,000	165,000	243

[1]Data are rounded to no more than three significant digits, except average value; may not add to totals shown.

[2]Average value is based on unrounded data and is rounded to the nearest dollar.

[3]Includes acoustic ceiling panels, pipe insulation, roof insulation board, and unspecified formed products.

[4]Includes explosives, high-temperature insulation, paint, refractory, soap, steel, sugar manufacture, and various unspecified industrial uses.

TABLE 4

PERLITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004[e]	2005[e]
Armenia[e]	35,000	35,000	35,000	35,000	35,000
Australia[e, 4]	5,000	5,000	5,000	5,000	5,000
Greece, screened	449,000	516,000	525,000	525,000	525,000
Georgia	NA	NA	NA [r]	45,000	45,000
Hungary[e, 4]	151,000	140,000	59,530 [r, 5]	59,800 [r]	145,000
Iran	18,130	20,000	26,495 [r]	31,259 [r, 5]	20,000
Italy[e]	60,000	60,000	60,000	60,000	60,000
Japan[e]	250,000	250,000	240,000	240,000	240,000
Mexico[4]	80,297	85,703	194,463 [r]	188,027 [r, 5]	195,000
Philippines[e]	6,000	6,000	6,000 [5]	6,000	6,000
Slovakia	14,910	18,630	19,000 [r]	19,000 [r]	19,000
South Africa[e]	400 [r]	400 [r]	400 [r]	400 [r]	400
Turkey[4]	70,738	151,902	136,633	133,829 [r, 5]	140,000
United States[5, 6]	588,000	521,000	493,000	508,000	508,000
Zimbabwe[e]	5,000	5,000	5,000	4,000 [r]	4,000
Total	1,730,000	1,810,000 [r]	1,810,000 [r]	1,860,000 [r]	1,950,000

[e]Estimated. [r]Revised. NA Not available.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Unless otherwise stated, figures represent processed ore output. Table contains data available through May 20, 2006.

[3]In addition to the countries listed, Algeria, Bulgaria, China, Cyprus, Iceland, Morocco, Mozambique, and Russia are thought to have produced perlite, but output is not reported, and available information is inadequate for the formulation of estimates of output levels.

[4]Crude ore.

[5]Reported figure.

[6]Processed ore sold and used by producers.

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PHOSPHATE ROCK

By Stephen M. Jasinski

Domestic survey data and tables were prepared by Hoa P. Phamdang, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

In 2005, U.S. marketable phosphate rock production increased to 36.3 million metric tons (Mt) from 35.8 Mt in 2004 (tables 1, 3). U.S. production capacity was 40 Mt, which was slightly lower than in 2004 owing to the closure of two mines (table 12). More than 90% of phosphate rock consumed was used to manufacture wet-process phosphoric acid for use in fertilizer products. The remainder was used for animal feed supplements, direct application to soil, and production of elemental phosphorus. World production was higher than in 2004 (table 13). The United States remained the world's leading producer, consumer, and importer of phosphate rock and the leading producer and supplier of phosphate fertilizers.

Phosphorus is an essential element for plant and animal nutrition and is consumed primarily as a principal component of nitrogen-phosphorus-potassium (NPK) fertilizers. Phosphate rock minerals are the only significant global resources of phosphorus. In this report (unless otherwise noted), mine production is reported in terms of marketable production, which refers to beneficiated phosphate rock with a suitable phosphorus pentoxide (P_2O_5) content for wet-process phosphoric acid or elemental phosphorus manufacturing. Percentages have been calculated using unrounded data.

Domestic Data Coverage

U.S. Geological Survey (USGS) domestic phosphate rock production data were obtained from monthly and semiannual voluntary canvasses of all companies that owned phosphate rock mines. All companies responded to the canvass in 2005. There were 14 active phosphate rock mines during the year; one mine, however, closed permanently in September, leaving 13 active mines at the end of the year (table 2).

Production

In 2005, phosphate rock was produced at nine mines in Florida, three in Idaho, and one each in North Carolina and Utah (table 2).

In Florida, the phosphate industry is concentrated in the counties of Hamilton, Hardee, Hillsborough, Manatee, and Polk. The nine mines that were active in the State in 2005 represented 72% of domestic annual production capacity. The Mosaic Company operated seven mines, and CF Industries, Inc. and PCS Phosphate Co., Inc. each operated one (table 2). In addition, PCS has a large integrated production facility in Beaufort County, NC, that includes a mine and animal feed, fertilizer, and phosphoric acid plants. All phosphate rock mining companies are vertically integrated with one or more fertilizer plants, usually located near the mine. Mosaic was the leading producing company with more than 50% of domestic phosphoric acid production capacity.

In September, Mosaic closed its Kingsford Mine in Polk County because of depleted reserves. The closure of the 40-year-old mine resulted in the elimination of 275 jobs. Mosaic also temporarily closed all its mines for 1 week in late November 2005 and from December 23, 2005, to January 3, 2006, to reduce inventory of phosphate rock that had accumulated owing to reduced production of phosphoric acid (Maready, 2005§[1]).

Mosaic ended its phosphate rock supply contract with U.S. Agri-Chemicals (USAC) (a subsidiary of Sinochem Corporation of China) in October. Mosaic had been supplying USAC 1.8 million metric tons per year (Mt/yr) of phosphate rock for phosphoric acid production at USAC's Fort Meade, FL, plant since 1994. USAC closed the plant and the associated Bartow, FL, facility that manufactured DAP and MAP after stocks of phosphate rock and phosphoric acid were exhausted in November (Mosaic Company, The, 2005b).

In the Western Phosphate Field, which is located in Idaho, Montana, Utah, and Wyoming, four mines were active in 2005—three in Idaho, and one in Utah (table 2). In Idaho, phosphate rock was mined in Caribou County by Nu-West Industries, Inc. (a subsidiary of Agrium Inc., Calgary, Alberta, Canada), P4 Production, LLC (a subsidiary of Monsanto Co.), and J.R. Simplot Co. Simplot also operated the Vernal Mine in Uintah County, UT.

Consumption

Domestic consumption of phosphate rock decreased slightly to 38.6 Mt from 39 Mt in 2004 (table 1). Phosphate rock sold and/or used as reported by the mining companies decreased slightly to 36 Mt from 36.5 Mt in 2004 (tables 1, 4). Consumption by grade and by region was withheld to avoid disclosing company proprietary data.

Phosphate rock was used primarily for production of wet-process phosphoric acid for fertilizer applications, which accounted for more than 90% of domestic consumption. The remainder was used in the manufacturing of animal feed supplements, for direct application to soil, and for elemental phosphorus production. According to the U.S. Census Bureau, production of phosphoric acid increased slightly to 11.6 Mt P_2O_5 content in 2005 from 11.5 Mt P_2O_5 content in 2004. Combined production of all types of phosphate fertilizers was 5% lower than in 2004. The major fertilizer products manufactured from phosphoric acid were diammonium phosphate (DAP) and monoammonium phosphate (MAP) (U.S. Census Bureau, 2006).

In 2005, Mosaic operated five wet-process phosphoric acid and fertilizer plants in Florida and one in Louisiana. In addition, Mosaic sold phosphate rock to USAC until it terminated their

[1]References that include a section mark (§) are found in the Internet References Cited section.

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sales agreement (Mosaic Company, The, 2006, p. 7). PCS had phosphoric acid and fertilizer production facilities near its mines in Florida and North Carolina. Simplot sent phosphate concentrate by a slurry pipeline; ore from its Smoky Canyon Mine in eastern Idaho went to Pocatello, ID, and ore from the Vernal Mine went to Rock Springs, WY.

Three companies—Agrifos Fertilizer LLC, Pasadena, TX; Mississippi Phosphates Corporation, Pascagoula, MS; and PCS Nitrogen, Inc., Geismar, LA—manufactured wet-process phosphoric acid using imported phosphate rock from Morocco. Agrifos and Mississippi Phosphates produced phosphate fertilizer products for domestic and export markets. PCS sold its phosphoric acid to Innophos, Inc., which has a nearby facility for upgrading phosphoric acid into high-purity acid for technical- and food-grade applications (Innophos, Inc., 2006, p. 9).

The Mississippi Phosphates facility suffered major damage from Hurricane Katrina, which made landfall west of Pascagoula, MS, on August 29. Flooding resulting from by the storm surge caused damage to electrical and instrumentation systems as well as to 25,000 metric tons (t) of DAP. In addition, a primary cooling tower was destroyed, and several buildings were damaged (Mississippi Phosphates Corporation, 2005). The plant reopened in February 2006 (Green Markets, 2006a). Mosaic experienced minor damage from the hurricane to its Louisiana facilities. The closure of oil refineries along the coast after the hurricane, however, resulted in a shortage of sulfur to phosphoric acid plants along the Gulf Coast for several weeks (Mosaic Corporation, The, 2005a).

Monsanto Company operated the only elemental phosphorus plant in the United States in Soda Springs, ID. The company used elemental phosphorus primarily to manufacture phosphorus trichloride, which was used as a chemical intermediary for the production of glyphosate-base herbicides (Monsanto Company, 2005, p. 10). In other countries, elemental phosphorus is used chiefly to manufacture high-purity phosphoric acid, by burning the phosphorus in water, which is known as thermal acid. Worldwide, there has been a gradual shift to manufacture high-purity phosphoric acid from wet-process acid, which has lower operating costs and none of the hazardous waste disposal issues that are associated with elemental phosphorus. Thermal acid, however, still accounts for 65% of annual world production capacity of high-purity phosphoric acid. China is the leading producer of elemental phosphorus in the world, with about 45 companies, most producing less than 10,000 metric tons per year (t/yr) of P_2O_5 (Jiang, 2006). The only other operating elemental phosphorus facilities in the world are located in Kazakhstan and the Netherlands (Duley, undated §).

Astaris LLC (a joint venture between Solutia, Inc. and FMC Corp.) was purchased by Israel Chemicals Ltd. (ICL) in September. Astaris and ICL were leading world producers of high-purity phosphoric acid and phosphorus chemicals for nonfertilizer applications. Astaris previously operated an elemental phosphorus plant that was closed in 2001 and a purified phosphoric acid plant that was sold and closed in 2003. After the sale, ICL had production facilities in North America and South America in addition to plants in China, Europe, and Israel (Taylor, 2005§).

The United States is considered a mature market for phosphate fertilizers, with an average consumption of slightly more than 4 Mt/yr during the past decade. In 2005, domestic consumption of P_2O_5 contained in fertilizers was 4.21 Mt, 4% less than 2004. Consumption of all types of primary nutrients (NPK) contained in fertilizers combined fell by 5% (Terry and Kirby, 2006, p. 6).

Stocks

Stocks of phosphate rock that were held by producers on December 31 fell by 3% compared with those of 2004. Data for the two regions were consolidated to avoid disclosing company proprietary information (tables 1, 3).

Transportation

In Florida and North Carolina, crude phosphate rock ore was sent by a slurry pipeline from the mines to the processing plants. Most beneficiated phosphate rock was used internally to manufacture wet-process phosphoric acid; the beneficiated phosphate rock was sent by conveyers to acid plants. The small amount of phosphate rock that was sold was delivered by rail. Mosaic sent beneficiated phosphate rock by rail to the Port of Tampa and then by barge across the Gulf of Mexico to its facilities in Louisiana. In central Florida, animal feed products, fertilizers, and phosphoric acid were sent by rail to domestic customers or to the Port of Tampa for export. The Port of Tampa handles the largest volume of fertilizer materials in the world (Tampa Port Authority, 2006§).

In northern Florida, PCS transported its fertilizer products by rail to consumers; some materials, however, were sent by rail to the PCS port facility at Morehead City, NC, for export. PCS used barges and tugboats to move products from its Aurora, NC, complex to the Port of Morehead City for export or delivery by rail to domestic consumers. Phosphoric acid producers along the Gulf of Mexico received phosphate rock by ship from Morocco and transported their products by barge on the Mississippi River and its tributaries or by rail for domestic consumers. In Idaho and Utah, phosphate rock was sent from the mine to the processing facility via truck, rail, and slurry pipelines.

Prices

The average sold or used price increased to $29.20 per metric ton from $27.76 per ton in 2004 (tables 1, 5). Price data were collected through the semiannual canvass of producers and reflected the value of phosphate rock sold or used for phosphoric acid and elemental phosphorus production. A small amount was sold on a long-term contract and was included in the average price. Unlike many other mineral commodities, no standard domestic or world price for phosphate rock exists. Average ranges of world prices were published in various industry trade journals based on a sample of transactions. The import price of $40.91 per ton was based on the U.S. Census Bureau customs value and included cost, insurance, and freight (table 1).

Foreign Trade

U.S. producers reported no exports of phosphate rock in 2005 (table 1). The phosphate rock export table has been eliminated because domestic producers have ceased exporting rock.

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Previous reports in this series have used U.S. Census Bureau export statistics to avoid disclosing proprietary data; the U.S. Census Bureau, however, includes reexports of phosphate rock by traders, which inflate the reported figure.

Exports of elemental phosphorus declined to 12,900 t in 2005 from 13,400 t in 2004; the reported customs value, however, increased to $2,000 per ton in 2005 from $1,694 per ton in 2004 (table 10).

The United States is the leading exporter of phosphate fertilizers in the world, accounting for about 45% of world P_2O_5 exports (Prud'homme, 2005). In 2005, total exports of P_2O_5 contained in fertilizer products increased slightly as higher DAP and phosphoric acid exports offset drops in MAP and triple superphosphate (tables 6, 9). Exports of DAP grew based on the strength of sales to India, which increased to 1.18 Mt from 426,000 t in 2004. The leading producers of phosphate fertilizers in India were hampered by shortages of phosphoric acid and higher raw materials costs, requiring imports to meet higher demand (Soomar, 2006). Sales to China fell for the third consecutive year because China continued to expand its domestic production capacity. MAP exports fell by 15% mainly because of lower fertilizer consumption in Brazil.

The United States is the leading importer of phosphate rock in the world. More than 75% of the shipments from Morocco were used by the three phosphoric acid producers located along the Gulf of Mexico. The remainder of Moroccan imports reportedly was used by Mosaic at its plants in Florida and Louisiana (Fertilizer Week, 2005b). In 2005, imports were estimated to be 2.63 Mt, based on U.S. Census Bureau data and export information received from Office Chérifien des Phosphates (OCP), the Moroccan phosphate producer (Bahcine Sendal, OCP, written commun., January 24, 2005). The U.S. Census Bureau withholds tonnage and value information for some phosphate rock and fertilizer product shipments, which necessitates the use of other data sources. The tonnage of U.S. imports of phosphate fertilizer products was insignificant compared with that of exports of the same fertilizer materials (table 11).

World Industry Structure

World production of marketable phosphate rock was 147 Mt, a 4% increase compared with that of 2004 (tables 1, 13). The United States with 36.3 Mt, China with 30.4 Mt, and Morocco with 25.2 Mt were the leading producing countries, accounting for 63% of production. The reported figure for production of phosphate rock in China was from official Chinese statistics. However, according to several sources, actual production of phosphate rock in China was about 45 Mt, with the inclusion of production at the numerous small, independent phosphate rock mines that were excluded from official statistics (Prud'homme, 2005).

World production of phosphoric acid was estimated to have grown by about 4% compared with that of 2004. China and India accounted for more than one-half of the increase in production. World consumption of phosphate acid for fertilizers was estimated to have decreased by about 2.4% from that of 2004 because of the combination of higher operating rates and lower MAP production. Phosphate fertilizer production grew slightly in 2005 (Prud'homme, 2005).

World Review

Brazil.—Yara ASA of Norway and Bunge Ltd. of Brazil entered into a 50:50 joint venture to conduct a feasibility study to develop the Anitapolis phosphate deposit in southern Brazil. This is the only known major phosphate rock deposit that has not been mined in Brazil. Yara had obtained a 54% share of the reserves in 2000 when it acquired Brazilian fertilizer company Adubos Trevo, and Bunge already held a 46% stake in the reserves. Yara sold 4% of the share of the reserves to Bunge to create an equal joint venture. The companies did not release information on the scope of the project (Fertilizer Week, 2005c).

Morocco.—OCP entered into two significant joint ventures in 2005 to produce phosphoric acid and fertilizer products. The largest agreement, in terms of tonnage, was signed with Sinochem to supply 750,000 t/yr of DAP to China from 2007 to 2011. OCP opened a new 850,000-t/yr DAP plant in December to supply its partners; however, its production capacity is expected to increase marginally because of ongoing refurbishment of existing DAP plants at Jorf Lasfar. The facility was planned to be at full capacity in mid-2006 (Middle East Economic Digest, 2005).

OCP and Bunge entered into an agreement to construct a new 375,000-t/yr phosphoric acid and 300,000-t/yr DAP, MAP, and TSP plant at Jorf Lasfar. The facility was expected to be completed in 2008 (Office Chérifien des Phosphates, 2005).

Nauru.—Australian Company Incitec Pivot Ltd. signed an agreement with the Government of Nauru to restart phosphate mining and to refurbish the associated processing plant. Pivot will provide materials and engineering to the new company, Republic of Nauru Phosphate Company, that was established by the Government of Nauru (Australian Broadcasting Corporation, 2005§). Phosphate rock production had diminished to about 11,000 t in 2005 because of depletion of reserves. Phosphate rock mining is the only industry on the small island nation, and the gradual decline of the mining industry has resulted in a near collapse of the country's economy and the lack of funds to improve mining methods to develop the remaining phosphate deposits. Pivot estimated that it could produce about 500,000 t/yr for 3 to 5 years (Australian Associated Press, 2005§).

Peru.—Brazilian firm Companhia Vale do Rio Doce (CVRD) won an auction held by the Peruvian Government to explore and develop the Bayovar phosphate deposit in the Piura region of northern Peru. CVRD estimated that the deposit had 816 Mt of reserves, and it has proposed mining about 3 Mt/yr of phosphate concentrate. Under the terms of the sale, a feasibility study must be completed in 2 years and production must begin in 5 years (Fertilizer Week, 2005a).

Outlook

U.S. phosphate rock production and consumption were expected to be lower in 2006 owing to the planned closure of one mine and two phosphoric acid plants, in addition to the closures of 2005 (Green Markets, 2006b). Several new mines were planned in Florida, but detailed permitting procedures and public opposition have slowed development. The new mines would be replacements for existing mines during the next decade and would not increase U.S. capacity.

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U.S. production of phosphate fertilizers is dependent upon export sales, primarily of MAP to Brazil and DAP to China, India, and South Asia. MAP sales to Brazil were expected to increase in 2006, while DAP sales to India were dependent upon the level of domestic production and government subsidy programs. China continued to increase production of DAP and MAP; however, imports of DAP will still be needed to meet growing consumption and because of regional transportation issues and lack of production capacity. China imports most of its DAP from the United States, but with a new joint venture between Chinese and Moroccan producers planned to start in 2007, exports of DAP from the United States are expected to decrease in the future.

According to the International Fertilizer Industry Association, world phosphate fertilizer consumption in 2006 was expected to increase by 2.4% after falling in 2005, and growth was expected to be concentrated in Asia and South America. Domestic phosphate fertilizer consumption was expected to fall slightly in 2006 (Prud'homme, 2005).

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TABLE 1

SALIENT PHOSPHATE ROCK STATISTICS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

	2001	2002	2003	2004	2005
United States:					
Mine production (crude ore)	130,000	154,000	153,000	146,000	159,000
Marketable production:					
Quantity:					
Gross weight	31,900	36,100	35,000	35,800	36,300
P_2O_5 content	9,230	10,700	10,300	10,400	10,500
Value	856,000	993,000	946,000	995,000	993,000
Value, average[2] dollars per metric ton	26.82	27.47	27.01	27.79	27.34
Sold or used by producers:[3]					
Quantity:					
Gross weight	32,800	34,700	36,400	36,500	36,000
P_2O_5 content	9,500	10,300	10,600	10,500	10,400
Value[4]	879,000	962,000	981,000	1,010,000	1,050,000
Value, average dollars per metric ton	26.81	27.69	26.95	27.76	29.20
Exports:					
Quantity, gross weight	9 [5]	62 [5]	64 [5]	-- [6]	-- [6]
Value[6]	W	W	W	--	--
Value, average dollars per metric ton	W	W	W	XX	XX
Imports for consumption[e, 5, 7]					
Quantity, gross weight	2,500	2,700	2,400	2,500	2,630
Value, cost, insurance, and freight[e]	123,000	112,000	84,000	91,300	107,000
Value, average dollars per metric ton	49.30	41.45	35.55	36.50	40.91
Consumption, gross weight[e, 8]	35,300	37,400	38,800	39,000	38,600
Stocks, December 31, producers	7,510	8,860	7,540	7,220	6,970
World, production, gross weight	126,000	135,000	138,000 [r]	141,000	147,000 [e]

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data. XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits, except average values per metric ton.

[2]Average value based on the sold or used values.

[3]Includes domestic sales and exports.

[4]Total value of all domestic and export sales.

[5]Source: U.S. Census Bureau.

[6]Reported by producers.

[7]Includes some estimated phosphate rock tonnage imported from Morocco but not reported by the U.S. Census Bureau.

[8]Expressed as sold or used plus imports minus exports.

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TABLE 2
ACTIVE PHOSPHATE ROCK MINES IN THE UNITED STATES IN 2005

Owner	Mine	County and State
CF Industries, Inc.	South Pasture	Hardee, FL.
Mosaic Co., The	Fort Green	Polk, FL.
Do.	Four Corners	Hillsborough/Manatee/Polk, FL.
Do.	Hookers Prairie	Polk, FL.
Do.	Hopewell	Hillsborough, FL.
Do.	Kingsford[1]	Polk/Hillsborough, FL.
Do.	South Fort Meade	Polk, FL.
Do.	Wingate Creek	Manatee, FL.
Nu-West Industries, Inc. (Agrium US, Inc.)	Dry Valley	Caribou, ID.
P4 Production, LLC. (Monsanto Co.)	South Rasmussen	Do.
PCS Phosphate Co., Inc.	Aurora	Beaufort, NC.
Do.	Swift Creek	Hamilton, FL.
Simplot, J.R, Co.	Smoky Canyon	Caribou, ID.
Do.	Vernal	Uintah, UT.

[1]Closed in September 2005.

TABLE 3
PRODUCTION OF PHOSPHATE ROCK IN THE UNITED STATES, BY REGION OR PERIOD[1]

(Thousand metric tons and thousand dollars)

	Mine production, crude ore		Marketable production, beneficiated			
Period or region	Rock	P_2O_5 content	Rock	P_2O_5 content	Value[2]	Ending stocks, rock
2004:						
Florida and North Carolina	138,000	12,900	30,400	8,930	859,000	W
Idaho and Utah	7,310	1,650	5,390	1,450	136,000	W
Total	146,000	14,500	35,800	10,400	995,000	7,220
2005:						
January-June	81,700	7,830	18,900	5,450	509,000	6,760
July-December	77,000	6,980	17,400	5,050	485,000	6,970
Total	159,000	14,800	36,300	10,500	993,000	XX

W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Based on the per ton sold or used values.

TABLE 4
PHOSPHATE ROCK SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY REGION OR PERIOD[1]

(Thousand metric tons and thousand dollars)

Period or region	Rock	P_2O_5 content	Value[2]
2004:			
Florida and North Carolina	31,600	9,210	890,000
Idaho and Utah	4,920	1,280	123,000
Total	36,500	10,500	1,010,000
2005:			
January-June	17,600	5,070	525,000
July-December	18,400	5,320	526,000
Total	36,000	10,400	1,050,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free on board mine.

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TABLE 5
VALUE OF U.S. PHOSPHATE ROCK, BY GRADE

(Dollars per metric ton, free on board mine)

Grade [percentage of bone phosphate of lime (BPL) content[1]]	2004	2005
66 to less than 70	W	W
60 to less than 66	27.82	29.12
Average weighted[2]	27.76	29.20

W Withheld to avoid disclosing company proprietary data.

[1]1.0% BPL (tricalcium phosphate)=0.458% P_2O_5.

[2]Includes less than 60% and greater than 70%, in addition to the grades listed.

TABLE 6
U.S. EXPORTS OF SUPERPHOSPHATES (CONCENTRATED)

(Thousand metric tons)

Country	2004	2005
Argentina	8	--
Australia	75	41
Brazil	108	38
Chile	57	28
Japan	25	37
Other	44	24
Total	317	168

-- Zero.

Source: U.S. Census Bureau.

TABLE 7
U.S. EXPORTS OF DIAMMONIUM PHOSPHATE[1]

(Thousand metric tons)

Country	2004	2005
Argentina	365	197
Australia	227	259
Brazil	189	104
Canada	131	119
Chile	67	83
China	1,430	1,330
Colombia	127	113
Ecuador	76	50
Guatemala	36	90
India	426	1,180
Japan	296	244
Kenya	87	49
Mexico	400	381
New Zealand	115	137
Pakistan	412	642
Peru	118	118
Thailand	95	118
Turkey	55	68
Other	387	342
Total	5,040	5,620

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 8
U.S. EXPORTS OF MONOAMMONIUM PHOSPHATE[1]

(Thousand metric tons)

Country	2004	2005
Argentina	289	223
Australia	756	625
Brazil	1,020	522
Canada	623	609
Chile	83	70
Colombia	123	134
India	--	335
Japan	125	136
Mexico	161	161
Other	245	79
Total	3,420	2,890

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 9
U.S. EXPORTS OF PHOSPHORIC ACID[1]

(Thousand metric tons)

Country	2004	2005
Canada	17	20
Colombia	2	9
India	60	250
Other	79	144
Total	158	423

[1]Excludes superphosphoric acid tonnage.

Source: U.S. Census Bureau.

TABLE 10
U.S. EXPORTS OF ELEMENTAL PHOSPHORUS[1]

	2004		2005	
Country	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Brazil	10,800	$16,300	9,120	$15,800
Canada	718	1,880	872	2,180
Japan	4	7	56	133
Korea, Republic of	5	10	22	46
Mexico	1,520	3,250	2,420	6,840
Taiwan	7	14	--	--
Other	334	1,200	366	800
Total	13,400	22,700	12,900	25,800

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Free alongside ship values.

Source: U.S. Census Bureau.

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TABLE 11

U.S. IMPORTS FOR CONSUMPTION OF PHOSPHATE ROCK AND PHOSPHATIC MATERIALS[1]

(Thousand metric tons and thousand dollars)

Phosphatic materials	2004		2005	
	Quantity	Value[2]	Quantity	Value[2]
Phosphate rock:				
Unground[3]	969	27,300	1,200	44,600
Ground[3]	510	26,600	518	27,300
Total[4]	2,500	91,300	2,630	107,000
Dicalcium phosphate	7	7,280	6	8,310
Elemental phosphorus	17	32,600	19	44,100
Normal superphosphate	(5)	83	1	169
Triple superphosphate	62	10,400	8	5,600
Diammonium phosphate	31	12,900	10	9,130
Fertilizer containing nitrates and phosphates	1	611	2	1,080
Phosphoric acid	71	22,900	58	27,900

[1]Data are rounded to no more than three significant digits.

[2]Declared cost, insurance, freight values.

[3]Some phosphate rock tonnages and values were suppressed by the U.S. Census Bureau.

[4]Includes an estimate for data suppressed by U.S. Census Bureau based on reported Moroccan exports to the United States.

[5]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 12

PHOSPHATE ROCK ANNUAL WORLD PRODUCTION CAPACITY, DECEMBER 31, 2005[1]

(Thousand metric tons)

Region/country	Capacity
Africa	52,000
Asia	33,600
Europe and Russia	14,200
Latin America and Canada	7,000
Middle East	15,300
Oceania	2,700
United States	40,000
Total	165,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Sources: International Fertilizer Industry Association and U.S. Geological Survey.

TABLE 13

PHOSPHATE ROCK, BASIC SLAG, AND GUANO: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Commodity and country[3]	Gross weight					P_2O_5 content				
	2001	2002	2003	2004	2005	2001	2002	2003	2004	2005
Phosphate rock:										
Albania[e]	1	1	--	--	--	(4)	(4)	--	--	--
Algeria	939	740	905	1,014 r	878	280 e	230 e	280 e	300 r, e	260 e
Australia	1,893	2,025	2,285	2,014	2,050 e	438	482	545	490	550 e
Brazil, concentrate	4,805 r	5,084	5,584 r	6,074 r	6,100 e	1,708	1,831	2,005 r	2,181 r	2,200 e

See footnotes at end of table.

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TABLE 13—Continued

PHOSPHATE ROCK, BASIC SLAG, AND GUANO: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Commodity and country[3]	Gross weight					P_2O_5 content				
	2001	2002	2003	2004	2005	2001	2002	2003	2004	2005
Phosphate rock—Continued:										
Burkina Faso	1	2	2 e	2 e	2 e	(4)	1	1 e	1 e	1 e
Canada e	800	1,000	1,000	1,000	1,000	300	380	380	380	380
Chile	19	20	21	21	21 e	5	5	5	5	5 e
China e	21,000	23,000	25,200	25,500	30,400	6,300	6,900	7,550	7,650	9,130
Christmas Island e	568 5	500	500	655 r	685	190 5	167	167	210 r	220
Colombia e	43	43	43	43	43	8 5	8	8	8	8
Egypt, beneficiated	972	1,550	2,183	2,219	2,730 e	293	434 e	630	650 e	800 e
Finland e	750	800 r	800 r	840 r	825	277	290 r	290 r	306 r	301
India e	1,200	1,250	1,175	1,180	1,200	355	370	345	349	355
Indonesia e	1	1	1	1	1	(4)	(4)	(4)	(4)	(4)
Iran	213	303	194	230	250 e	26 e	36 e	23 e	28 e	30 e
Iraq, beneficiated e	300	300	30	3 r	3	100	100	10	1 r	1
Israel	3,511	3,476	3,208	2,947	2,900 e	1,115	1,110 e	1,020 e	900 e	880 e
Jordan	5,843	7,179	6,763	6,223	6,230 e	1,928	2,340	2,230 e	2,050 r	2,060 e
Kazakhstan	97	137	169	230	230 e	28	40	38	52 e	52 e
Korea, North e	350	300	300	300	300	105	95	95	95	95
Mexico	787	5 r	6 r	(4) r	--	236	1 r	2 r	(4) r	--
Morocco 6	21,983	23,041	22,877	25,369 r	25,200 e	7,400	7,700	7,400	8,500 e	8,300 e
Nauru e	266 5	150	84	22	11	100 5	55	26	7	3
Pakistan e	11	11	11	11	11	2	2	2	2	2
Peru	16 e	16 e	32	38 r	38 e	5	6	12	14 r	14 e
Philippines e	450	400	400	400	400	148	135	135	135	135
Russia e	10,500	10,700	11,000	11,000	11,000	3,900	4,000	4,000	4,000	4,000
Senegal	1,708	1,551 r	1,765 r	1,754 r	1,520	615	554 r	630 r	626 r	543
South Africa	2,420	2,803	2,643	2,735	2,577	995	1,086	1,030 e	1,067	1,000 e
Sri Lanka	35	39	41	42 e	43 e	12	13	14	14 e	15 e
Syria	2,043	2,483	2,414	2,883	3,500 e	613 e	745 e	725 e	870 e	1,050 e
Tanzania	4	1	4	7 r	7	1	(4)	1	2 r	2
Thailand	2	4	14	3 r	3 e	1 e	1 e	4 e	1 e	1 e
Togo	1,067	1,271	1,471	1,115	1,215	380 e	460 e	530 e	418 r, e	368 e
Tunisia, washed e	8,144 5	7,461 r, 5	7,890	7,954 r, 5	8,000	2,440	2,200 r	2,300	2,400 e	2,400 e
United States	31,900	36,100	35,000	35,800	36,300	9,230	10,700	10,600	10,400	10,500
Uzbekistan e	200	425	430	430	430	47	101	102	102	102
Venezuela e	399 5	390 5	260 5	250	250	114	111	75	70	67
Vietnam e	677	680	823 r	800 r	820	225	204	247 r	240 r	246
Zimbabwe, concentrate	87	108	95	83	50 e	28	39	31	27	16 e
Total	126,000	135,000	138,000 r	141,000	147,000	40,000 r	42,900 r	43,500 r	44,600 r	46,100
Basic (Thomas converter) slag: e										
Egypt	7	7	7	7	8	2	2	2	2	2
France	50	50	50	50	50	8	8	8	8	8
Germany	200	200	150	150	150	20	20	18	18	18
Luxembourg	475	475	475	450	475	70 r	70 r	70 r	70 r	70
Total	732	732	682	657	683	100 r	100 r	98 r	98 r	98

eEstimated. rRevised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through May 3, 2006. Data for major phosphate rock-producing countries derived in part from the International Fertilizer Industry Association; other figures are from official country sources where available.

[3]Phosphate rock may be produced in Nigeria, but information is inadequate to estimate output.

[4]Less than ½ unit.

[5]Reported figure.

[6]Includes production from Western Sahara.

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PLATINUM-GROUP METALS

By Micheal W. George

Domestic survey data and tables were prepared by Mahbood Mahdavi, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

In 2005, Stillwater Mining Company (SMC) (Billings, MT) was the only domestic mine producer of platinum-group metals (PGMs) from its Stillwater Mine near Nye, MT, and its East Boulder Mine south of Big Timber, MT. SMC was majority owned by Mining and Metallurgical Company (MMC) Norilsk Nickel (Moscow, Russia). SMC produced 17,200 kilograms (kg) of PGMs in 2005, 3% less than the 17,700 kg that it produced in 2004 (Stillwater Mining Company, 2006, p. 4).

In 2005, the domestic automobile industry continued to be the major consumer of PGMs. Autocatalysts accounted for approximately 87% of rhodium consumption, 71% of palladium consumption, and 52% of platinum consumption.

Production

Primary.—During 2005, the Stillwater Mine produced 9,110 kg of palladium and 2,730 kg of platinum. The decrease in production at the Stillwater Mine was caused by a reallocation of resources to development rather than mine production. Production from the East Boulder Mine was 4,200 kg of palladium and 1,180 kg of platinum (Stillwater Mining Company, 2006, p. 4-6, 9). Palladium and platinum production for SMC were down by 2.5% and 3.1%, respectively, compared with those of 2004. SMC defined mine production as the quantity of PGMs contained in concentrate at the time it was shipped to the smelter. The company milled 1.16 million metric tons (Mt) of ore from the mines, slightly more than in 2004. In 2005, the average mill head grade for the mines declined to 16.5 grams per metric ton (g/t) combined palladium and platinum from 17.1 g/t in 2004 (Stillwater Mining Company, 2006, p. 1).

SMC processed ore from the mines through a flotation concentrator adjacent to the mine shaft. The mill had a recovery rate for PGMs of 92%. The flotation concentrate, 1.5% of the original ore on a dry weight basis, was filtered and transported to the company's metallurgical complex in Columbus, MT.

At the SMC metallurgical complex, the concentrates from both mines are processed first at the precious metal smelter. The concentrate, which contains 1 to 2 kilograms per metric ton (kg/t) PGMs, is fed into an electric arc furnace (EAF) along with spent autocatalysts and limestone. The resulting matte, which contains 6 to 8 kg/t PGMs, is granulated and fed into a top-blown rotary converter (TBRC). The furnace slag is shipped back to the Stillwater Mine mill to capture more of the PGMs. The TBRC produces matte that contains 12 to 19 kg/t PGMs that is granulated and transported to the refinery. The slag from the TBRC is returned to the EAF for further treatment. The smelter has an offgas processing facility that captures more than 99.7% of the sulfur dioxide (SO_2) produced by the smelter and produces gypsum cake that is sold to a local agricultural supply wholesaler.

The refinery has several circuits that further process the smelter matte to produce PGM filter cake, nickel sulfate hexahydrate crystals, and copper cathodes. The PGM filter cake contains 60% to 65% PGMs and is shipped to Johnson Matthy plc (London, United Kingdom) facilities in the United States and to Heraeus Precious Metal Management, Inc. (New York, NY) for further refining.

SMC's proven and probable reserves are contained in the J-M Reef, a 45-kilometer-long ore body in the Beartooth Mountain Range in south-central Montana. At the end of 2005, the company had a total proven and probable reserve of 750,000 kg (24.1 million troy ounces) of palladium and platinum, with a metal ratio of 3.5 to1 palladium to platinum. In 2005, the proven reserves increased by 33% compared with 2004 proven reserves owing to the completion of diamond drilling program in 2005 (Stillwater Mining Company, 2006, p. 17).

PolyMet Mining Corp. (Vancouver, British Columbia, Canada) announced that it had purchased an ore processing facility in northeastern Minnesota. The former taconite plant was to be used for processing NorthMet project ore from northeastern Minnesota, which includes cobalt, copper, gold, nickel, and PGMs. If a mine is developed, it would be the first combined base- and precious-metal mine in the State of Minnesota and the third PGM mine in the United States (PolyMet Mining Corp., 2005).

Secondary.—In 2005, recovery and recycling of autocatalysts provided a growing secondary source of PGMs. The strength of the price of platinum in 2005, which averaged $900 per troy ounce, helped support the profitability of the recovery and recycling businesses. The global recovery of platinum from autocatalysts rose by 12% in 2005, reaching 24,000 kg, with recovery increasing in Europe and North America. In North America, recovery of platinum from catalytic converters rose by more than 2,000 kg in 2005 to an estimated 15,000 kg of platinum. Japan, however, recovered 36% less platinum from scrapped autocatalysts in 2005; this could be attributed to the exporting of used cars and a reduced number of end-of-life vehicles (Kendal, 2006, p. 20-23).

Global palladium recovered from autocatalysts in 2005 was 20,000 kg, an increase of 19% compared with that of 2004. In Europe, a combination of higher palladium loading on autocatalysts plus the greater number of autocatalysts being recycled led palladium recovery to increase by 50% to 5,000 kg compared with that of 2004. Palladium recovery in North America increased by 13% to 12,000 kg. In Japan, recovery of palladium dropped to 900 kg, a 25% decrease compared with recovery in 2004. As with platinum, the reason for this drop was the exporting of used automobiles (Kendal, 2006, p. 32-35).

In 2005, global recovery of rhodium slipped slightly to 4,000 kg. Increased recoveries in Europe and North America were

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more than offset by a decrease in recovery in Japan (Kendal, 2006, p. 40).

SMC's recycling program processed 190 metric tons (t) or 9 metric tons per day of spent catalysts from automobiles and from oil refineries in 2005, 27% more than in 2004. SMC's goal was to double the amount of scrap material processed. Adding more scrap material to the smelter adds little to the overall operating cost of production and increases the grade of the matte (Stillwater Mining Company, 2006, p. 8).

Consumption

In 2005, global platinum sales were about 208,000 kg, a 2% increase compared with that of 2004. Increased use of platinum in catalytic converters was partially offset by a decrease in platinum demand from the jewelry industry owing to the increase in the price for that metal. Increased sales of diesel cars in Europe, rising light vehicle (passenger and light trucks) output, and tighter emission regulations combined to increase the consumption of platinum in autocatalysts to 119,000 kg, about a 9% increase compared with that of 2004. Palladium global sales also increased in 2005 to 219,000 kg, a 7% increase compared with those of 2004. The increase was driven by the rapid growth of palladium jewelry production in China and growth in the use of palladium in autocatalysts and electronics (Kendal, 2006, p. 2-10).

In 2005, U.S. apparent consumption of refined platinum was estimated to be about 89,600 kg, and apparent domestic palladium consumption was estimated to be 126,000 kg.

Palladium.—Worldwide consumption of palladium rose to 218,000 kg in 2005, a 7% increase compared with consumption in 2004. Palladium used in jewelry continued to increase, rising by 54% to 44,500 kg in 2005 compared with 2004 consumption. China, which accounted for most of the growth, consumed about 37,000 kg, 83% of the world consumption of palladium for jewelry manufacture. The majority of the remaining palladium consumption for jewelry was by Japanese jewelry manufactures, with some consumption in Europe and the United States (Kendal, 2006, p. 8-11, 32-39).

Palladium consumption for the production of autocatalysts remained relatively unchanged in 2005. There was a large increase in demand from auto makers in China, Japan, and the Republic of Korea that was offset by a drop in production of gasoline light vehicles in Europe and the United States (Kendal, 2006, p. 32).

Palladium consumption in dental alloys remained stable at 26,300 kg, with Japan as the major consumer. The chemical industry consumed 9,950 kg in 2005, a 3% increase compared with that of 2004. The main uses of palladium in the chemical industry were as catalysts in manufacturing bulk chemicals, including purified terephthalic acid (PTA). In 2005, much of the increased consumption was owing to construction of new PTA capacity in several countries, including Brazil, China, and Mexico. PTA ultimately is used in the production of polyester fibers and polyerhylene terephalate (PET). The electronics industry increased its consumption of palladium by 5% in 2005 to 30,000 kg. Most of the palladium used in the electronics industry was for multilayer ceramic capacitors for uses in all types of electronic goods (Kendal, 2006, p. 37-39).

Platinum.—Growth in the diesel-powered light vehicle sector in Europe continued to be the major reason for the increase in consumption of platinum in autocatalysts. In 2005, European automakers consumed 61,000 kg of platinum, an increase of 8,700 kg. Sales of diesel vehicles continued to rise, and about one-half of all new light vehicles in Western Europe was diesel. Although the rate of economic growth in Europe slowed in 2005, new European Stage IV emissions requirements and the introduction of catalyzed soot filters led to the increasing platinum loading on diesel autocatalysts. Soot filters are not required under European Stage IV emission regulation; however, some countries have adopted soot filters because of public concern.

The use of platinum in China and Japan also increased. In China, the consumption of platinum used in autocatalysts jumped to 3,500 kg in 2005 from 2,300 kg in 2004 owing to increased production of light vehicles and more stringent emission regulations. Japan saw an increase in consumption of platinum for autocatalysts owing to increased automobile production and increased emission regulations on light vehicles and heavy-duty diesel vehicles. In North America, the demand for platinum increased slightly despite the drop in light vehicle production in 2005 (Kendal, 2006, p. 5).

In 2005, global consumption of platinum in jewelry dropped by 9% compared with consumption in 2004, to 61,000 kg, the lowest level since 1995, largely as a result of high and volatile prices. A 13% decrease in purchases of metal by Chinese jewelry manufacturers in 2005 compared with purchases in 2004 was attributed to the higher price of platinum. With the large price surge, many jewelers also reduced their inventories of platinum jewelry, which led to a reduction of platinum jewelry on display. Retail demand for platinum jewelry also suffered losses to palladium and white gold jewelry. In Europe, however, sales remained stable owing to a growth in the platinum bridal jewelry market in the United Kingdom (Kendal, 2006, p. 5-6).

Global use of platinum in chemical catalysts rose by 3% in 2005 to 10,400 kg compared with that of 2004. Consumption of platinum-base catalysts for the production of silicon increased owing to increased silicon manufacturing capacity in Asia. The purchases of platinum by the petroleum refining industry increased to 15,000 kg in 2005 because of increased refining capacity. The global use of platinum in electronics increased by 20% to 11,000 kg in 2005. Growth in the sales of computer hard disks accounted for much of the growth in consumption, with greater production of PGM-bearing thermocouplers and other electronics adding to the increase in consumption (Kendal, 2006, p. 6).

Platinum consumed in the production of liquid crystal display (LCD) glass and other glasses increased in 2005 by 22% to 11,000 kg compared with that of 2004 with most of the increased consumption coming from increased capacity in the LCD industry in Asia. Consumption in other end uses, such as anticancer drugs, coatings on turbine engines, medical components, oxygen sensors in automobiles, and spark plugs, increased slightly, while consumption of platinum in dental alloys decreased slightly in 2005. Consumption of platinum-base catalysts used in offroad equipment and stationary emissions controls remained about the same at 600

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kg. Worldwide consumption of platinum coins and small bars remained unchanged in 2005; however, there was a net return of about 500 kg of large platinum bars in Japan to the investment market (Kendal, 2006, p. 26-27). U.S. Mint sales of platinum American Eagle Bullion coins remained unchanged in 2005 (U.S. Mint, 2006§[1]).

Other PGMs.—Global rhodium consumption in 2005 rose by 11% to 25,000 kg compared with that of 2004. A majority of this was used in the production of autocatalysts. Other uses of rhodium were, in descending order, LCD glass manufacturing, chemicals, electrical applications, and jewelry (Kendal, 2006, p. 40).

Global consumption of ruthenium increased by 17% to 24,500 kg in 2005. A 30% increase in ruthenium consumption in electronics was partially offset by a drop in chemical uses. Electrochemical and other end-use demand remained unchanged. Some of the uses for ruthenium in electronics are conductive paste used in resistor components, hard disks, and plasma display panels. Consumption of iridium, which is used in similar industries as ruthenium, increased to 3,860 kg in 2005, a 3% increase compared with 2004 consumption (Kendal, 2006, p. 41).

Prices

According to Platts Metals Week, the 2005 annual average price of palladium was $203.54 per troy ounce, which was a 13% decrease compared with that of 2004. Prices had increased in 2004 after trending down since 2000 when the price had averaged $692 per troy ounce. The average annual platinum price in 2005 reached $899.51 per troy ounce, a more than 6% increase compared with the average annual 2004 price. As for the other PGMs, the iridium 2005 annual price decreased by 9% compared with the 2004 price, the rhodium 2005 annual price increased by 110%, and the ruthenium 2005 annual price increased by 16%.

Palladium.—The price of palladium began the year at $184 per troy ounce and remained near the $200 per troy ounce level for much of the year. In October, the price started a climb that peaked on December 9 at $297 per troy ounce and promptly dropped to $255 per troy ounce at yearend.

Platinum.—The price of platinum began the year at $858 per troy ounce and remained below the $900 per troy ounce level for the first half of the year. In August, the price of platinum rose above the $900 per troy ounce level for 2 weeks before falling back under $900 per troy ounce. After 2 weeks of price fluctuations just below the $900 per troy ounce level, the price began a climb, reaching $1,019 per troy ounce on December 12, the highest price in nearly 25 years. The price quickly fell to $968 per troy ounce by yearend.

Rhodium.—The price of rhodium reached a 14-year high of $3,110 per troy ounce on November 17. This was a 139% increase compared with the January 3 price of $1,300 per troy ounce. The price had been increasing since early 2004 when the price was $500 per troy ounce. The price increase was attributed to the declining availability of the metal. With less metal for sale from Russia and increasing consumption from automobile, chemical production, and glass there was less material available. Speculation reportedly also played a part in the increase in prices.

Other PGMs.—The price of iridium began the year at $170 per troy ounce and decreased to $145 per troy ounce on February 18 where it remained until early April. The price began a slow climb and ended the year at $195 per troy ounce. The price of ruthenium followed a similar trend to that of iridium, starting the year at $67 per troy ounce and dropping to $55 per troy ounce on February 17. The price began to rise in early March to end the year at $87 per troy ounce.

Trade

In 2005, the U.S. net import reliance as a percentage of apparent consumption was estimated to be 89% for refined palladium and 96% for refined platinum. Imports of refined palladium in 2005 increased by 10% to 139,000 kg from 127,000 kg in 2004, with three countries accounting for about 85% of refined palladium imports in 2005—Russia (46%), South Africa (23%), and the United Kingdom (15%). A large portion of the Russian imports was shipments from Norilsk Nickel to SMC as part of a purchase agreement. Imports of platinum, including waste, scrap, and coins, increased by 23% in 2005 to 106,000 kg from 86,400 kg in 2004, with four countries accounting for 72% of imports of platinum in 2005—South Africa (38%), the United Kingdom (17%), Canada (10%), and Germany (7%). Other refined PGM imports were up by 13% in 2005 compared with those of 2004. South Africa accounted for 60%, Germany accounted for 19%, and the United Kingdom accounted for 16% of other PGM imports in 2005. The United States exported 45,600 kg of platinum (48, 400 kg in 2004), 27,000 kg of palladium (31,500 kg in 2004), 1,070 kg of other PGM (1,090 kg in 2004), and 615 kg of rhodium (314 kg in 2004).

World Industry Structure

In 2005, world mine production of PGMs increased by about 5% to 515,000 kg compared with 492,000 kg in 2004 (table 5). South Africa, the world's leading producer of PGMs, accounted for 61% of total mine production in 2005, Russia accounted for 28%, Canada accounted for 4%, and the United States accounted for 3%. South Africa, which accounted for 78% of world platinum production, increased its output of platinum by 6% in 2005 to 169,000 kg. Global output of palladium climbed to 222,000 kg, with Russia and South Africa accounting for 44% and 38%, respectively, of the total. South Africa dominated the world's mine production of other PGMs with 77% of the total.

World Review

Canada.—North American Palladium Ltd. (Toronto, Ontario, Canada) produced about 5,510 kg of palladium and 586 kg of platinum in 2005 at the Lac des Iles Mine compared with 9,610 kg of palladium and 782 kg of platinum in 2004. Lower ore grade, poor mill availability, and a drop in recoveries led to the

[1]A reference that includes a section mark (§) is found in the Internet Reference Cited section.

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41% decrease in PGM production (North American Palladium Ltd., 2006, p. 1-5). The rest of Canada's PGM production was a byproduct of nickel mining in the Sudbury and Raglin areas. Inco Limited (Toronto) and Falconbridge Limited (Toronto) were the main producers of byproduct PGM. In 2005, Inco produced 13,000 kg of PGMs and, although Falconbridge did not release data for PGM production, nickel production dropped in 2005 (Kendal, 2006, p. 18).

Madagascar.—Jubilee Platinum plc (London) increased the pace of exploration (comprising reconnaissance, geochemical soil sampling, trenching, and geophysics) on its three copper-nickel-PGM properties—Ambodilafa, Lanjanina, and Londokomanana, (Jubilee Platinum plc, 2006).

Russia.—In 2005, Russia accounted for 44% of global mine production of palladium, 21% of other PGM production, and 14% of platinum production. Despite the importance of the Russian PGM mining industry to the world market, information on production, reserves, and sales have historically been difficult to obtain because such data were considered to be confidential under Russian law. In late 2003, a bill to declassify PGM data (with the exception of Government stocks and sales) was enacted. Although the bill was to take effect in February 2004, the publication of PGM data was delayed by regulatory procedures (O'Neil, 2004). In 2005, however, Norilsk disclosed that it produced 97,400 kg of palladium and 23,400 kg of platinum. Micon International conducted an independent audit of the deposits on the Taimyr Peninsula and as of December, reported reserves of 2,540 t of PGM (1,930 t of palladium, 497 t of platinum, and 112 t of other PGM) (MMC Norilsk Nickel, 2006, p. 1, 13, 98).

Serbia and Montenegro.—RTB BOR Grupa Rudarsko Topionicarski Basen BOR D.O.O. in Serbia, which previously recovered palladium and platinum from copper ores and was the country's only producer of PGMs, closed in 2005 (Walter Steblez, Serbia and Montenegro country specialist, U.S. Geological Survey, oral commun., June 14, 2006).

South Africa.—South Africa accounted for 78% of platinum, 38% of palladium, and 61% of all PGMs produced worldwide in 2005. In 2005, South African production of PGMs was up by 9% compared with that of 2004; palladium production rose by 8%, platinum production rose by 6%, and other PGM production rose by 21%.

PGM production by Anglo Platinum Limited (Johannesburg, South Africa) was 127,000 kg in and accounted for 41% of the total South African PGM production in 2005. Platinum production was unchanged compared with 2004 production, but palladium production was up by 3% and that of other PGM was up by more than 30%. The primary reasons for the increase in PGM production were the two pool and share agreements (P&SA) with Aquarius Platinum Limited (Johannesburg). The first P&SA was at the Kroondal Platinum Mine, and in July, Anglo and Aquarius signed the second P&SA for the Marikana operations. The P&SAs allow the companies to pool their assets while retaining ownership and sharing the proceeds equally. Production arising from Kroondal is sold to Impala Platinum Limited (Implats) (Johannesburg) under a volume-based concentrate offtake agreement. The commitment in terms of this agreement was expected to be met from the shafts already in production at commencement of the second P&SA and was expected to be fully met during 2007 at current production rates. Additional production arising from the expansion made possible by the P&SA will be smelted and refined by Anglo, which had several potential new projects in South Africa and was expected to remain the leading producer of PGMs in the world (Anglo Platinum Limited, 2006, p. 1-10, 51-55).

Refined production of PGMs from Implats increased by 6% to 36,000 kg compared with production in 2004. The increase was owing to a 7% increase in mill throughput, but was offset slightly by lower grade ore (Impala Platinum Holdings Limited, 2006).

Northam Platinum Limited (Johannesburg) processed 17% more ore in 2005 than in 2004. The main reason for the increase was that production in 2004 had been reduced by a fire, which had closed the mine for about 6 weeks (Kendal, 2006, p. 15).

In June, Lonmin Plc (London) purchased Southern Platinum (Toronto) for $190 million. This purchase added the Limpopo division (formally Messina Platinum Ltd. when under Southern Platinum Corp.). In 2005, Lonmin produced 30,000 kg of platinum, up by 4% compared with platinum production in 2004 (Kendal, 2006, p. 14-15).

On November 29, Aquarius announced the first shipment of concentrates from the Everest Platinum Mine in South Africa. The mine produced 220 kg of PGMs in 2005, and Aquarius expected the open pit and underground mine near the town of Lydenburg on the eastern limb of the South African Bushveld Complex to produce 7,000 kg of PGMs in 2006 (Aquarius Platinum Limited, 2006, p. 1-8).

African Rainbow Minerals' Limited (ARM) (Sandton, South Africa) platinum division had several joint ventures operating in South Africa—Modikwa Platinum Mine, 50% jointly owned with Anglo; Nkomati Nickel Mine, 50% with LionOre Mining International Ltd. (Toronto); and Two Rivers Platinum Mine, a project in which ARM held 55% and Implats 45%. The Two Rivers Project was expected to start up in the second half of 2006 and was projected to produce 6,500 kilograms per year (kg/yr) of PGMs (African Rainbow Minerals Limited, 2006, p. 43-45).

A bankable feasibility study was completed on Ridge Mining plc's (London) Blue Ridge Mine in November. The mine was projected to start up in mid-2006 and had a projected capacity of 3,890 kg/yr of PGMs (Ridge Mining plc, 2006).

Zimbabwe.—In 2005, Zimplats Holdings Limited (Harare, Zimbabwe), which owned Zimbabwe's Hartley Complex, produced 2,700 kg of platinum and 2,240 kg of palladium which was unchanged compared with production in 2004. The introduction of underground mining lowered the amount of ore milled; this was offset, however, by an increase in ore grade (Zimbabwe Platinum Mines Limited, 2006).

Implats, which owns 86.9% of Zimplats, announced that it had increased PGM production by 9% at the Minmosa, Zimbabwe, 50-50 joint venture with Aquarius, compared with production in 2004. In 2005, Mimosa produced 2,240 kg of platinum, 1,680 kg of palladium, and 170 kg of rhodium. Implats and Aquarius announced that an upgrade of the concentrator, planned for mid-2006, could increase the annual output of platinum to 2,690 kg (Kendal, 2006, p. 19).

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Although Zimbabwe has proven to be a popular site for exploration and mining of PGMs, much of the refining takes place in South Africa. A recent proposal by the Government of Zimbabwe could result in the Government taking a substantial stake in foreign-owned domestic mining operations. Although further upgrades to capacity and the possibility of building new refineries in Zimbabwe were investigated in 2005, the proposal from the Government caused foreign investors to become reluctant to invest in new operations (Kendal, 2006, p. 19).

Current Research and Technology

In 2005, there were numerous technological advances that required PGMs. Many of these were associated with fuel cells, medical devices, nanotechnology, and pharmaceuticals. It was unknown how these new technologies would affect the consumption of PGMs or the patterns of PGMs consumption.

Outlook

An increase in diesel car sales in Europe can be expected to cause a strong increase in the use of platinum in the region in 2006 and beyond. Stricter emissions regulation in China, Europe, Japan, and other parts of the world is also expected to lead to higher average platinum loadings on catalysts, especially on light-duty diesel vehicles, as particulate matter emissions become more closely controlled. In the United States, thrifting to reduce platinum loadings in catalysts is continuing at most manufacturers and is likely to lead to a reduction in the use of platinum in autocatalysts. The price differential of more than $600 per troy ounce between palladium and platinum has led to the assumption that automobile manufacturers will change PGM ratios in gasoline-engine vehicle's catalytic converters in favor of palladium, causing automotive industry use of palladium to increase in the short term. Average loading levels on autocatalysts are expected to increase in Europe and Japan at the expense of platinum as more stringent particulate emission standards are introduced. Since U.S. automobile manufacturers sharply drew down their palladium stocks during 2005, purchases of palladium by U.S. automobile manufacturers are likely to increase. Also, many U.S. automobile manufacturers had yet to make the switch because of the historically high and volatile prices. A shift toward greater use of palladium in preference to platinum on gasoline-vehicle autocatalysts by a number of manufacturers is also likely to provide a modest increase in palladium use in Asia and Europe. In Europe, however, production of gasoline fueled automobiles is expected to decline while sales of diesel engines continue to rise, which will partially offset some of the expected growth from switching to palladium, as will further thrifting by all catalyst producers. In the electronics sector, component sales are expected to increase. Increased demand for palladium, however, will be somewhat offset by a combination of miniaturization and substitution of nickel and silver for palladium in multilayer ceramic capacitors. The sale of platinum jewelry is expected to drop worldwide, assuming the price continues to be high and white gold and palladium are used as substitutes.

There was a believed to be a supply shortfall of platinum in 2005, but supplies of platinum are expected to increase significantly from new mines opening in South Africa. However, since the growth in supply is expected to be about the same as the projected growth in demand, a supply deficit is expected to continue. As for palladium there was a perceived oversupply of palladium in the world in 2005. However, a supply deficit could develop as production of palladium will most likely remain flat or decline and demand is expected to grow.

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TABLE 1
SALIENT PLATINUM-GROUP METALS STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Mine production:						
Palladium, Pd content:[2]						
Quantity	kilograms	12,100	14,800	14,000	13,700	13,300
Value	thousands	$237,000	$162,000	$91,400	$102,000	$87,100
Platinum, Pt content:[2]						
Quantity	kilograms	3,610	4,390	4,170	4,040	3,920
Value	thousands	$61,900	$76,500	$93,100	$110,000	$113,000
Refinery production:						
Palladium, Pd content:						
Quantity	kilograms	9,790	5,700	7,250	5,480	5,470
Value	thousands	$192,000	$62,200	$47,300	$41,000	$35,800
Platinum, Pt content:						
Quantity	kilograms	15,000	15,200	17,000	16,700	16,100
Value	thousands	$258,000	$265,000	$379,000	$456,000	$466,000
Imports for consumption, refined:						
Iridium, Ir content	kilograms	3,110	2,100	2,200	3,230	3,010
Osmium, Os content	do.	77	36	53	75	39
Palladium, Pd content	do.	160,000	117,000	105,000	127,000	139,000
Platinum, includes waste, scrap, and coins, Pt content	do.	84,200	84,700	88,500	86,400	106,000
Rhodium, Rh content	do.	12,400	8,630	12,000	13,200	13,600
Ruthenium, Ru content	do.	8,170	9,890	15,900	18,800	23,200
Exports, refined:						
Iridium, osmium, and ruthenium, gross weight	do.	252	94	145	1,090 r	1,070
Palladium, Pd content	do.	36,800	42,700	22,300	31,500 r	27,000
Platinum, Pt content	do.	29,300	27,800	22,200	20,000 r	20,700
Rhodium, Rh content	do.	982	349	479	314 r	615
Stocks, National Defense Stockpile, December 31:						
Iridium, Ir content	do.	784	784	562	501	189
Palladium, Pd content	do.	16,300	5,870	1,170	568	--
Platinum, Pt content	do.	3,680	649	649	649	261
Price, average:						
Iridium[3]	dollars per troy ounce	$415.25	$294.62	$93.02	$185.33	$169.51
Palladium[4]	do.	$610.71	$339.68	$203.00	$232.93	$203.54
Platinum[4]	do.	$533.29	$542.56	$694.44	$848.76	$899.51
Rhodium[4]	do.	$1,600.00	$838.88	$530.28	$983.24	$2,060.00
Ruthenium[3]	do.	$130.67	$66.33	$35.43	$64.22	$74.41
Employment		1,620	1,580	1,540	1,580	1,620
World, mine production, PGM content	kilograms	410,000 r	430,000 r	465,000 r	492,000 r, e	515,000 e

eEstimated. rRevised. -- Zero.

[1]Data are rounded to three significant digits, except prices.

[2]Source: Stillwater Mining Co., 2005 annual report, p. 4.

[3]Price data are annual averages of daily Engelhard unfabricated quotations published in Platts Metals Week.

[4]Price data are annual Engelhard unfabricated quotations published in Platts Metals Week.

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TABLE 2

U.S. IMPORTS FOR CONSUMPTION OF PLATINUM, BY COUNTRY[1]

Country	Grain and nuggets		Sponge		Other unwrought		Other		Waste and scrap		Coins	
	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)
2004	376	$9,520	68,800	$1,830,000	6,710	$178,000	4,550	$105,000	5,870	$82,000	12	$345
2005:												
Australia	--	--	--	--	--	--	1,470	42,300	3,610	2,000	5	176
Austria	--	--	--	--	1	10	(2)	3	--	--	--	--
Azerbaijan	--	--	2	52	--	--	--	--	--	--	--	--
Belgium	--	--	1,540	42,900	1	33	(2)	10	--	--	--	--
Brazil	--	--	604	17,500	--	--	1	20	(2)	7	--	--
Canada	10	313	--	--	2	43	333	9,610	10,500	20,000	3	95
Chile	--	--	--	--	--	--	--	--	353	6,100	--	--
China	--	--	--	--	--	--	(2)	4	63	2,040	1	24
Colombia	60	1,700	11	286	104	2,860	--	--	296	2,100	--	--
Dominican Republic	--	--	--	--	--	--	--	--	21	245	--	--
El Salvador	--	--	--	--	--	--	--	--	--	--	--	--
France	--	--	--	--	1	9	1	13	319	452	--	--
Germany	--	--	3,750	108,000	264	6,050	3,830	55,300	79	274	--	--
Greece	--	--	--	--	(2)	2	--	--	--	--	--	--
Hong Kong	--	--	--	--	--	--	--	--	3	108	1	21
India	2	55	40	745	2	54	--	--	--	--	--	--
Ireland	--	--	--	--	--	--	6	152	--	--	--	--
Israel	--	--	--	--	(2)	3	--	--	--	--	1	9
Italy	51	1,350	412	12,300	598	16,300	300	7,000	--	--	--	--
Japan	--	--	314	8,860	121	2,990	253	6,770	1,580	18,600	--	--
Jordan	--	--	--	--	--	--	--	--	12	133	--	--
Korea, Republic of	--	--	--	--	93	2,790	(2)	5	5,280	18,000	--	--
Malaysia	--	--	--	--	--	--	--	--	1,090	16,700	--	--
Mauritius	--	--	--	--	--	--	(2)	3	--	--	--	--
Mexico	--	--	--	--	--	--	--	--	2,480	22,000	--	--
Netherlands	--	--	--	--	--	--	15	205	--	--	(2)	16
Norway	--	--	704	20,200	--	--	--	--	--	--	--	--
Philippines	--	--	--	--	--	--	1	10	2,420	1,430	--	--
Russia	--	--	3,820	107,000	186	5,040	95	2,550	--	--	--	--
Saudi Arabia	--	--	--	--	--	--	--	--	6	5	--	--
Singapore	--	--	--	--	(2)	4	--	--	30	829	--	--
South Africa	137	3,870	40,000	1,130,000	33	993	36	672	--	--	--	--
Spain	--	--	--	--	--	--	--	--	--	--	--	--
Suriname	--	--	--	--	--	--	--	--	(2)	8	--	--
Sweden	--	--	--	--	1	18	--	--	--	--	--	--
Switzerland	1	14	739	21,700	2	56	85	1,640	--	--	9	127

See footnotes at end of table.

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TABLE 2—Continued

U.S. IMPORTS FOR CONSUMPTION OF PLATINUM, BY COUNTRY[1]

Country	Grain and nuggets		Sponge		Other unwrought		Other		Waste and scrap		Coins	
	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)
2005—Continued:												
Taiwan	(2)	$2	--	--	--	--	--	--	--	--	--	--
Thailand	--	--	--	--	--	--	--	--	215	$5,840	--	--
United Kingdom	97	2,700	16,200	$466,000	333	$10,800	589	$17,400	738	21,600	3	$103
Total	358	10,000	68,200	1,940,000	1,740	48,000	7,020	144,000	29,100	138,000	23	571

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau; data adjusted by the U.S. Geological Survey.

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TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF PLATINUM-GROUP METALS, BY COUNTRY[1]

Country	Unwrought palladium		Palladium, other		Iridium[2]		Unwrought osmium		Unwrought ruthenium		Rhodium[3]	
	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Ir content (kilograms)	Value (thousands)	Quantity, Os content (kilograms)	Value (thousands)	Quantity, Ru content (kilograms)	Value (thousands)	Quantity, Rh content (kilograms)	Value (thousands)
2004	106,000	$786,000	20,700	$145,000	3,230	$18,000	75	$421	18,800	$35,900	13,200	$397,000
2005:												
Austria	--	--	13	44	--	--	--	--	--	--	--	--
Azerbaijan	1	6	--	--	--	--	--	--	--	--	--	--
Belgium	2,330	14,300	119	1,100	--	--	--	--	--	--	720	33,500
Canada	1,610	13,200	--	--	--	--	--	--	--	--	(4)	3
Chile	40	299	--	--	--	--	--	--	--	--	--	--
China	270	1,860	--	--	--	--	4	22	--	--	--	--
Dominican Republic	--	--	2	9	--	--	--	--	--	--	--	--
France	--	--	47	176	--	--	--	--	--	--	(4)	2
Germany	1,670	12,200	562	2,700	403	2,110	4	55	6,360	15,700	833	48,100
Ireland	--	--	--	--	1	9	--	--	--	--	--	--
Israel	--	--	--	--	--	--	--	--	--	--	9	590
Italy	1,720	9,990	787	5,190	--	--	--	--	--	--	74	4,330
Japan	1,980	8,660	1,470	1,740	--	--	--	--	32	78	17	1,120
Korea, Republic of	--	--	--	--	--	--	--	--	--	--	16	1,310
Norway	6,120	37,100	12	343	--	--	--	--	--	--	7	446
Russia	54,600	342,000	9,680	52,600	--	--	21	203	108	185	915	54,900
Singapore	--	--	--	--	--	--	--	--	60	120	78	5,000
South Africa	32,400	190,000	--	--	1,150	5,950	10	83	14,700	30,900	7,800	474,000
Spain	15	92	--	--	--	--	--	--	--	--	--	--
Switzerland	1,160	9,330	1,570	9,450	--	--	--	--	280	558	--	--
Thailand	--	--	--	--	--	--	--	--	--	--	1	25
United Kingdom	20,200	137,000	945	6,370	1,450	8,650	--	--	1,610	2,240	3,110	198,000
Total	124,000	776,000	15,200	79,700	3,010	16,700	39	362	23,200	49,800	13,600	821,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Unwrought and other forms of iridium.

[3]Unwrought and other forms of rhodium.

[4]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 4

U.S. EXPORTS OF PLATINUM-GROUP METALS, BY COUNTRY[1]

Country	Palladium		Platinum		Platinum, waste and scrap		Iridium, osmium, ruthenium		Rhodium	
	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, gross weight (kilograms)	Value (thousands)	Quantity, Rh content (kilograms)	Value (thousands)
2004	31,500 r	$143,000 r	20,000	$377,000 r	28,400 r	$520,000 r	1,090 r	$8,800 r	314 r	$7,900 r
2005:										
Argentina	5	35	131	3,440	--	--	--	--	--	--
Australia	343	2,520	529	15,500	--	--	--	--	--	--
Austria	2	9	28	483	--	--	--	--	--	--
Belarus	61	117	--	--	--	--	--	--	--	--
Belgium	140	748	37	1,020	73	695	1	7	(2)	10
Bermuda	1	7	--	--	--	--	--	--	--	--
Bolivia	(2)	7	--	--	--	--	--	--	(2)	8
Brazil	608	4,180	371	8,650	10	162	(2)	13	--	--
Bulgaria	19	40	--	--	--	--	--	--	--	--
Cambodia	--	--	(2)	5	--	--	--	--	--	--
Canada	3,160	20,900	858	20,100	2,040	19,400	4	22	121	7,040
Chile	--	--	552	8,430	--	--	--	--	--	--
China	276	1,390	547	9,290	16	149	14	248	1	47
Colombia	22	161	3	54	--	--	--	--	(2)	8
Costa Rica	1	7	--	--	--	--	--	--	--	--
Cyprus	--	--	(2)	4	--	--	(2)	5	--	--
Czech Republic	--	--	3	43	--	--	--	--	--	--
Denmark	86	539	3	49	--	--	--	--	--	--
Dominican Republic	11	69	(2)	5	--	--	--	--	--	--
Ecuador	--	--	1	11	--	--	--	--	--	--
Estonia	2	9	--	--	--	--	--	--	--	--
Finland	11	95	7	114	--	--	--	--	--	--
France	543	2,810	93	1,260	--	--	7	41	--	--
Germany	3,750	14,500	2,190	47,400	1,460	16,100	77	620	78	6,040
Greece	--	--	2	31	--	--	--	--	--	--
Guatemala	--	--	--	--	--	--	--	--	(2)	7
Haiti	3	17	--	--	--	--	--	--	--	--
Hong Kong	570	2,230	786	18,900	--	--	224	1,350	2	329
Hungary	1	3	1	10	--	--	--	--	--	--
Iceland	9	56	1	24	--	--	--	--	--	--
India	9	31	21	380	6	231	(2)	9	6	1,090
Indonesia	--	--	(2)	9	--	--	--	--	--	--
Ireland	74	150	98	1,990	--	--	3	17	--	--
Israel	759	2,090	2	48	--	--	6	34	--	--
Italy	205	1,380	1,770	51,800	3	91	--	--	10	583
Japan	2,150	12,600	5,840	126,000	1,660	44,000	179	1,220	58	4,450
Korea, Republic of	346	962	99	2,300	56	472	4	52	--	--
Kuwait	5	41	(2)	15	--	--	--	--	--	--
Lebanon	21	54	--	--	--	--	--	--	(2)	4
Liechtenstein	5	45	1	11	--	--	--	--	--	--
Malaysia	21	138	57	685	--	--	360	2,340	--	--
Mexico	47	375	389	8,050	--	--	20	137	4	581
Netherlands	97	637	52	849	--	--	--	--	--	--
New Zealand	47	366	6	94	--	--	--	--	--	--
Norway	68	777	31	487	--	--	--	--	--	--
Philippines	1	14	14	211	--	--	--	--	--	--
Poland	3	14	1	20	--	--	--	--	--	--
Qatar	1	11	--	--	--	--	--	--	--	--
Romania	1	8	6	103	--	--	--	--	--	--

See footnotes at end of table.

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TABLE 4—Continued

U.S. EXPORTS OF PLATINUM-GROUP METALS, BY COUNTRY[1]

Country	Palladium		Platinum		Platinum, waste and scrap		Iridium, osmium, ruthenium		Rhodium	
	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, Pt content (kilograms)	Value (thousands)	Quantity, gross weight (kilograms)	Value (thousands)	Quantity, Rh content (kilograms)	Value (thousands)
2005—Continued:										
Russia	--	--	2	$34	--	--	--	--	--	--
Saint Kitts and Nevis	4	$6	--	--	--	--	--	--	--	--
Saudi Arabia	3	27	4	46	--	--	--	--	--	--
Singapore	57	296	15	304	--	--	30	$143	(2)	$21
Slovakia	--	--	5	119	--	--	--	--	--	--
Slovenia	8	20	--	--	--	--	--	--	--	--
South Africa	25	147	863	15,200	--	--	--	--	--	--
Spain	301	1,460	7	105	--	--	--	--	--	--
Suriname	--	--	5	67	--	--	--	--	--	--
Sweden	30	324	70	1,110	1	$6	--	--	--	--
Switzerland	642	5,230	1,380	19,200	--	--	(2)	9	(2)	32
Taiwan	3,660	9,550	857	21,000	--	--	92	514	279	4,940
Thailand	203	763	109	1,480	--	--	(2)	11	2	302
Turkey	5	35	6	118	--	--	--	--	--	--
United Arab Emirates	1	7	1	26	--	--	--	--	(2)	55
United Kingdom	8,560	33,700	2,830	60,600	19,600	401,000	53	394	54	3,340
Uruguay	33	181	--	--	--	--	--	--	--	--
Vietnam	--	--	1	21	--	--	--	--	--	--
Total	27,000	122,000	20,700	447,000	24,900	482,000	1,070	7,190	615	28,900

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau; data adjusted by the U.S. Geological Survey.

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TABLE 5
PLATINUM-GROUP METALS: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Kilograms)

Country[3]	2001	2002	2003	2004[e]	2005[e]
Palladium:					
Australia[4]	828	810	820 [e]	830	840
Botswana[e]	900	1,300	2,200	2,500	1,900
Canada	8,972 [r]	12,210 [r]	12,808 [r]	18,551 [r, 5]	15,000
Japan[6]	4,805	5,618	5,500 [e]	5,300 [r]	5,200
Poland[e, 7, 8]	12	12	12	12	12
Russia[e]	96,000 [r]	96,000 [r]	97,000 [r]	97,000 [r]	97,400
Serbia and Montenegro[e]	25	25	20	20	--
South Africa	62,601	63,758 [r]	70,946 [r]	78,455 [5]	84,908 [5]
United States[9]	12,100	14,800	14,000	13,700 [5]	13,300 [5]
Zimbabwe	371	1,943	3,449 [r]	3,564 [5]	3,879 [5]
Total	187,000 [r]	196,000 [r]	207,000 [r]	220,000 [r]	222,000
Platinum:					
Australia[e, 4]	174	200	225	230	240
Botswana[e]	200	300	500	500	300
Canada	7,733 [r]	9,202 [r]	6,990 [r, e]	7,813 [r, 5]	6,400
Colombia	674	661	828 [r, e]	1,209 [r, 5]	1,082 [p]
Finland	510	508	461 [r, e]	705 [r]	800
Japan[5]	791	762	770 [e]	750 [r]	730
Poland[e, 6, 7]	20	20	20	20	20
Russia[e]	27,000 [r]	27,000 [r]	28,000 [r]	28,000 [r]	30,000
Serbia and Montenegro[e]	5	5	5	5	--
South Africa	130,307	132,897 [r]	148,348 [r]	159,862 [r, 5]	168,749 [5]
United States[9]	3,610	4,390	4,170	4,040 [5]	3,920 [5]
Zimbabwe	519	2,306	4,270 [r]	4,438 [5]	4,834 [5]
Total	172,000 [r]	178,000 [r]	195,000 [r]	208,000 [r]	217,000
Other platinum-group metals:					
Canada[e]	720	700	799	800	800
Russia[e]	14,500	14,500	15,000 [r]	15,000 [r]	15,500
South Africa	37,005 [r]	39,986 [r]	46,856 [r]	48,265 [r, 5]	58,218 [5]
Zimbabwe	42	480	851 [r]	809 [5]	862 [5]
Total	52,300 [r]	55,700 [r]	63,500 [r]	64,900 [r]	75,400
Grand total	410,000 [r]	430,000 [r]	465,000 [r]	492,000 [r]	515,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through April 29, 2006. Platinum-group metal (PGM) production by Germany, Norway, and the United Kingdom is not included in this table because the production is derived wholly from imported metallurgical products and to include it would result in double counting.

[3]In addition to the countries listed, China, Indonesia, and the Philippines are believed to produce PGM, and several other countries may also do so, but output is not reported quantitatively, and there is no reliable basis for the formulation of estimates of output levels. A part of this output not specifically reported by country is, however presumably included in this table credited to Japan.

[4]PGM recovered from nickel ore that is processed domestically. PGM in exported nickel ore are extracted in the importing countries, such as Japan, and are believed to be included in the production figures for those countries.

[5]Reported figure.

[6]Production derived entirely from imported ores.

[7]Based on official Polish estimates.

[8]Estimates based on reported platinum and palladium-bearing final (residual) slimes and then average Pt and Pd content from electrolytic copper refining.

[9]A very small quantity of byproduct platinum and palladium produced from gold-copper ores was excluded.

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POTASH

By Dennis S. Kostick

Domestic survey data and tables were prepared by Joseph M. Krisanda, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

Potash production declined in quantity by 7% in 2005, but the total value of sales increased by 21% compared with that of 2004. In 2005, 2.5 million metric tons (Mt) of minerals was mined to produce 1.2 Mt of potassium oxide (K_2O) equivalent.[1] Imports for consumption decreased slightly; however, the customs value increased by 56%. Total exports were 11% lower in 2005 (table 1).

Potash denotes a variety of mined and manufactured salts, all of which contain the element potassium in water-soluble form. More than 85% of the domestic production of potash is near Carlsbad, NM, with most of the potash coming from the mineral sylvite. At the end of the 19th century, potash production came from hardwood trees and was a mixture of potassium carbonate and potassium hydroxide, both of which are caustic. Lye denoted sodium hydroxide, and potash lye was potassium hydroxide, a higher grade product that resulted in better grade of soap than the lye soap being used for laundry. The 1942 Webster's dictionary defined potash as potassium carbonate. Since approximately 1950, the term potash has been used to indicate potassic fertilizers, which are potassium chloride (KCl or sylvite), potassium sulfate [K_2SO_4 or sulfate of potash (SOP), usually a manufactured product], and potassium-magnesium sulfate [$K_2SO_4 \cdot 2MgSO_4$ or langbeinite or double sulfate of potash magnesia (SOPM or K-Mag)]. Muriate of potash (MOP) is an agriculturally acceptable mix of KCl (95% pure or greater) and sodium chloride (halite) for fertilizer use that includes minor amounts of other nontoxic minerals from the mined ore and is neither the crude ore sylvinite nor pure sylvite.

This publication has historically included potassium nitrate [KNO_3 or saltpeter or nitrate of potash (NOP), a mostly manufactured product] and mixed sodium nitrate and potassium nitrate ($NaNO_3$ and KNO_3 or Chilean saltpeter, a natural product) because it functions as a potassic plus nitrogenous fertilizer. Saltpeter and Chilean saltpeter are still noted in the import tables (tables 8, 9). Alunite, feldspar, and muscovite are potassium-bearing minerals that have a very low solubility in water and are considered to be neither potassic fertilizers nor ores for price-competitive potassic fertilizers.

Legislative and Government Programs

Foreign competition and rising domestic energy costs were factors presented by Intrepid Mining LLC (the leading U.S. potash producer) in its appeal to reduce the Federal royalty rate to 1% from 2% for 5 years. The Carlsbad potash industry has been affected the most since the early 1980s when there were seven mining operations; now there are only two. The Potash Royalty Reduction Act of 2004 (H.R. 4984) was introduced in the U.S. Congress to provide some financial relief for the New Mexico potash industry (Industrial Minerals, 2005b). A successor bill, the Potash Royalty Reduction Act of 2005 (H.R. 485), was passed by the U.S. House of Representatives on May 16, 2005 (Library of Congress, The, undated §[2]).

Production

Domestic production data were developed by the U.S. Geological Survey (USGS) from a semiannual voluntary canvass of U.S. operations. All seven of the operations canvassed for both semiannual surveys responded, representing 100% of the total production listed in table 1. Three companies produced potash from seven operations in three States. Most domestic production was from southeastern New Mexico where one company operated two mines and a second company operated one mine with multiple products. The second company also operated a deep-solution mine in Michigan. The third State with potash production was Utah where two companies produced potash from three operations.

Potash producers in the United States produced MOP, SOP, and SOPM. Published production data of all types and grades of potash in the United States have been adjusted since mid-1997 to avoid disclosing the proprietary data of companies that produce SOP and SOPM, which together are known as sulfates.

North American fertilizer producers posed higher earnings in 2005 despite a weak fertilizer application season in North America in fall 2004. High energy feedstock prices for ammonia and phosphate coupled with a weak demand for these fertilizers did not affect the potash industry. Although U.S. potash production and sales decreased in 2005, potash prices increased partially because of a tight North American supply market brought on because a Canadian potash producer signed an agreement to supply more than 2 Mt of potash each year to a Chinese potash importer.

Ashta Chemicals Incorporated announced it would construct a chloralkali plant to produce chlorine and coproduct potassium hydroxide (KOH), also known as caustic potash, in El Dorado, AR (Chemical Week, 2005c). The chlorine would supply Great Lakes Chemicals Corporation's adjacent facility that manufactures flame retardants. Construction of the plant was scheduled for late 2005 with completion slated for mid-2007. Ashta Chemicals has a KOH plant in Ashtabula, OH, that has capacity of 70,000 metric tons per year (t/yr) (Chemical Market Reporter, 2005b).

Consumption

Consumption of K_2O equivalent in 2005 was comparable to that of 2004. Decreases in production and imports coupled with a decrease

[1]"Because the amount of potassium in the common salts of potassium varies, the industry has established a common standard of measurement of defining a product's potassium content [or purity], in terms of equivalent percentages of potassium oxide (K_2O). A K_2O equivalent of 60 percent, 51 percent, and 22 percent is the customary minimum standard for muriate of potash, sulfate of potash, and double sulfate of potash magnesia products, respectively" (IMC Global, Inc., 2004, p. 8). All tonnages are reported in metric tons, K_2O equivalent, unless otherwise specified. All percentages are computed on unrounded K_2O equivalent values.

[2]References that include a section mark (§) are found in the Internet References Cited section.

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in exports led to flat apparent consumption. The principal use of potash is as an agricultural fertilizer (plant nutrient) because it is a source of soluble potassium, which is one of the three primary plant nutrients required for plant growth and maturation; the others are fixed nitrogen and soluble phosphorus. Potash and phosphorus are mined products, and fixed nitrogen is produced from the atmosphere using industrial processes. Modern agricultural practice uses large amounts of these primary nutrients and additional nutrients, such as boron, calcium, chlorine, copper, iron, magnesium, manganese, molybdenum, sulfur, and zinc, to ensure plant health and proper maturation. The three major plant nutrients have no cost-effective substitutes. Low-nutrient-content alternative sources, such as animal manure and guano, bone meal, compost, glauconite, and "tankage" from slaughterhouses, are available, but the cost of transportation per metric ton of nutrient can reduce their desirability beyond relatively short distances. In addition to its use as a fertilizer, potassium chloride is important in industrialized economies where it is used in aluminum recycling, by the chloralkali industry to produce potassium hydroxide, in metal electroplating, oil-well drilling mud, snow and ice melting, steel heat-treating, and water softening.

Potassium hydroxide is used for industrial water treatment and is the precursor of potassium carbonate, several forms of potassium phosphate, many other potassic chemicals, and soap manufacturing. The glass industry uses potassium carbonate for television and computer monitor production. Potassium carbonate is used to produce animal feed supplements, cement, some types of fire extinguishers, food products, photographic chemicals, and textiles. It is also used in brewing beer, pharmaceutical preparations, and as a catalyst for synthetic rubber manufacturing. Generally, these nonfertilizer uses have accounted for 15% of annual potash consumption in the United States.

According to the Potash and Phosphate Institute, agricultural MOP shipments to the 10 leading consuming States represented 67% of the combined Canadian and United States producers' total sales to the United States in 2005 (table 3). In decreasing order of tonnage, the States were Illinois, Iowa, Indiana, Minnesota, Ohio, Missouri, Wisconsin, Michigan, Georgia, and Florida. Nonagricultural MOP shipments by State for 2005 were not available; however, total nonagricultural potash sales increased by 5% in 2005 compared with those in 2004.

Foreign Trade

U.S. exports of potash have been decreasing during the past several years. In 2005, 200,000 metric tons (t) was exported, of which 42% was MOP, 39% was SOPM, 18% was SOP, and 1% was NOP (table 6). Mexico, Canada, Japan, and Costa Rica, in declining order, received 51% of the total exports of potash from the United States and all decreased their shipments, except Costa Rica, compared with those in 2004 (table 7). Of the total quantity of exports by world region, 35% went to North America, 22% went to South America, 18% went to Central America, 14% went to Asia, 5% went to the Caribbean, 4% went to Oceania, and the remainder went to Africa, Europe, and the Middle East. Exports of MOP to all regions declined by 26%, SOP increased by 6%, SOPM declined by 7%, and NOP decreased by 27% (table 6). Total potash exports decreased by 11% in 2005 compared with those of 2004.

Potash imports into the United States for 2005 remained flat at 4.92 Mt compared with those in 2004 (table 8). MOP imports were unchanged at 4.81 Mt, and mixed potassium salts declined by 86% to 798 t. SOP imports decreased slightly, whereas NOP imports increased slightly. The largest increase in MOP imports was from Russia, which shipped 317% more potash to the United States in 2005 than in 2004. Total potash imports from Canada for 2005 were down by 4% compared with those in 2004. Canada supplied 89% of the MOP imports to the United States and 87% of all potash imports (table 9). Chile was the leading supplier of NOP with 68% of the imports, followed by Israel with 29%. Imports of mixed potassium salts declined by 86% in 2005 from those in 2004.

World Industry Structure

Estimated 2005 world potash production increased slightly to 31 Mt (table 10). Western European production was estimated to have decreased by 3%, and production in all countries in the area declined slightly. The potash-producing countries of Eastern Europe—Belarus, Russia, and Ukraine—were estimated to have increased their combined total production by 8% to 9.65 Mt of K_2O equivalent compared with that of 2004. North American production decreased slightly to 11.3 Mt of K_2O equivalent.

World Review

Canada.—Canpotex Ltd. was established in 1970 by the producers of potash in Canada for the exclusive purpose of exporting potash for sale to nonproducing countries in Asia, Latin America, and Oceania. Canpotex competes for business with Belarus, Germany, Israel, Jordan, Russia, and Ukraine, supplying 30% of the potash requirements to the international markets it serves. Its members include Agrium Inc., Mosaic Canada ULC, and Potash Corp. of Saskatchewan Inc. (PCS).

In November 2004, Canpotex announced that Sinochem Corp. of China had signed a contract for 2005 to purchase 2.1 Mt of potash, including 1.5 Mt of red standard-grade potash, 300,000 t of granular-grade potash, and 300,000 t of white standard-grade potash. The quantity is 27% more than the sale in 2004. The contract includes a 10% additional volume provision with a price increase of at least $40 per metric ton compared with the past contract price. Because Sinochem purchases the product at the Vancouver port, it will be responsible for all shipping charges (Chemical Market Reporter, 2005c). This transaction should reduce North American potash supplies and provide an opportunity for the U.S. potash industry to increase its production.

The Provincial Government of Saskatchewan announced in April a 10-year tax relief from base payments on mine expansions of more than 200,000 t/yr of potassium chloride. The province also issued a capital investment incentive to promote greater production that would result in a pretax savings of $6.25 per ton. In response to this announcement, PCS planned to spend $275 million to restart 1.9 Mt of idled capacity at its Lanigan and Allan mines in Saskatchewan (Chemical Market Reporter, 2005c). Concurrently, Mosaic Company (the parent company of Mozaic Canada) announced it would add 400,000 t of new capacity at its Esterhazy, Saskatchewan mine (Mosaic Company, 2005§). Agrium also took advantage

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of this opportunity and announced plans to invest $65 million to increase capacity by 310,000 t/yr at its Vanscoy, Saskatchewan, potash mine. Construction began in July and would be completed by late 2006. When finished, the plant would have a total annual capacity of 2.1 million metric tons per year (Mt/yr) (Agrium Inc., 2005§). Agrium produced 1.7 Mt of potash valued at $200 million in 2004 (Chemical Week, 2005b). All three companies stated that they were evaluating further expansions or exploring new projects at other locations in the province. Agrium also purchased the fertilizer distribution business of Imperial Oil Company (a subsidiary of ExxonMobil Corporation) for $22 million in cash. Imperial had long-term leases for land at 190 independently operated retail outlets and exclusive fertilizer agreements with many independent operators that market more than 500,000 t/yr of fertilizer in western Canada (Chemical Week, 2005a).

Anglo Minerals Ltd. completed a feasibility study to mine potash in central Saskatchewan. The study indicated there was an inferred resource of 394 Mt of recoverable sylvinite grading 22.3% K_2O in the Upper Patience Lake stratigraphic submember and an inferred resource of 243 Mt of recoverable sylvinite grading 24.7% K_2O in the Lower Patience Lake submember. The company was seeking a partner to join the project. Additional drilling, coring, and seismic surveying were recommended in the study (Chemical Market Reporter, 2005a).

Germany.—K+S Kali GmbH finalized the acquisition the distribution and production activities of Société Commercial des Potasses et de l'Azote (SCPA) of France. The new company will be called K+S Kali & SCPA France S.A.S. One of the objectives of the merger was to strengthen the supply of potash and magnesium products and other fertilizer specialty products to French farmers (Industrial Minerals, 2005a).

Outlook

World demand for grain is expected to continue to increase in 2006. Factors affecting world economic growth include interest rates in the United States, China's foreign exchange policy, and global inflation. The world economic growth had been forecast to increase by 4.3% in 2005 compared with 5% in 2004 (Potash Corp. of Saskatchewan Inc., 2005, p. 46). The main driver in the growth of the potash market is expected to be rapid economic growth in many Asian, Central American, and South American nations. These increases, which are expected to continue into 2006, are projected to support expenditures on fertilizer.

After harvesting the best crop in years in 2004, the world's farmers had an improved financial position entering 2005, which supported increased fertilizer consumption to replace nutrients drawn from the soil by the large crop and helped farmers achieve their production goals (Potash Corp. of Saskatchewan, Inc., 2005, p. 46). The global consumption is projected to be 30.3 Mt of potash in 2009, equating to a growth rate of 2% per year (International Fertilizer Industry Association, 2005, p. 22). This growth rate suggests that 7 Mt of potash will be required worldwide.

Even though there was a small amount of remaining excess capacity worldwide at yearend, significant growth in production capacity is still needed to meet the anticipated increase in demand. In the period from 2005 to 2009, potash capacity expansions will come online but will be localized in established producing countries. Triggered by strong demand projections, limited spare capacity, and firming international prices, most suppliers have announced expansion plans. There could be future potash developments in Argentina, Canada, Congo (Kinshasa), Russia, and Thailand, and most of the new capacity will be located in exporting countries. These projects have the possibility of adding more than 9.8 Mt of MOP capacity in the longer term (International Fertilizer Industry Association, 2005, p. 17-22).

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TABLE 1
SALIENT POTASH STATISTICS[1, 2]

(Thousand metric tons and thousand dollars unless otherwise specified)

		2001	2002	2003	2004	2005
United States:						
Production:[3]						
Gross weight		2,500	2,600	2,400	2,700	2,500
K_2O equivalent		1,200	1,200	1,100	1,300	1,200
Sales by producers:						
Quantity:						
Gross weight[3]		2,400	2,500	2,500	2,700	2,500
K_2O equivalent[3]		1,100	1,200	1,200	1,300	1,200
Value[4, 5]		260,000	280,000	280,000	340,000	410,000
Average value:[6]						
Gross weight	dollars per metric ton	$110	$110	$110	$125	$165
K_2O equivalent	do.	$230	$230	$230	$270 r	$350
Exports:						
Gross weight		883	894	801	640 r	569
K_2O equivalent		366	371	329	233 r	200
Imports for consumption:[7, 8]						
Quantity:						
Gross weight		7,480	7,630	7,810	8,140	8,110
K_2O equivalent		4,540	4,620	4,720	4,920	4,920
Value, customs		537,000	615,000	646,000	751,000 r	1,170,000
Consumption, apparent:[9]						
Gross weight[10]		9,000	9,200	9,500	10,000	10,000
K_2O equivalent[10]		5,300	5,300	5,400	6,000	6,000
World, production, marketable K_2O equivalent		26,400	26,800 r	28,400	30,400 r	31,100 e

eEstimated. rRevised. NA Not available.

[1]Includes muriate of potash, sulfate of potash, potassium magnesium sulfate, and some parent salts. Excludes other chemical compounds that contain potassium.

[2]Data are rounded to no more than three significant digits unless otherwise specified.

[3]Data rounded to within 100,000 metric tons (t) to avoid disclosing proprietary data.

[4]Free on board mine.

[5]Data are rounded to no more than two significant digits.

[6]Rounded to the nearest $5 to avoid disclosing proprietary data.

[7]Excludes potassium chemicals and mixed fertilizers.

[8]Includes nitrate of potash.

[9]Calculated from sales plus imports minus exports.

[10]Data rounded to within 200,000 t to avoid disclosing proprietary data.

TABLE 2
PRODUCTION OF CRUDE ORE IN NEW MEXICO

(Thousand metric tons)

	Crude salts,[1] mine production[2]	
Period	Gross weight	K_2O equivalent
2004:		
January-June	6,000	700
July-December	5,000	600
Total	11,000	1,300

See footnotes at end of table.

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TABLE 2—Continued
PRODUCTION OF CRUDE ORE IN NEW MEXICO

(Thousand metric tons)

Period	Crude salts,[1] mine production[2]	
	Gross weight	K_2O equivalent
2005:		
January-June	6,000	700
July-December	5,000	600
Total	11,000	1,300

[1]Sylvinite and langbeinite.
[2]Data are rounded to the nearest 1,000 metric tons to avoid disclosing company proprietary data.

TABLE 3
SALES OF NORTH AMERICAN MURIATE OF POTASH, BY STATE OF DESTINATION[1]

(Metric tons of K_2O equivalent)

State	Agricultural potash		Nonagricultural potash	
	2004	2005	2004	2005
Alabama	76,500	53,800	236,000	NA
Alaska	1,250	1,230	2,360	NA
Arizona	2,730	4,340	3,020	NA
Arkansas	73,200	43,000	56	NA
California	78,100	66,800	17,600	NA
Colorado	13,600	13,800	19,400	NA
Connecticut	966	603	1,380	NA
Delaware	22,100	20,300	47,200	NA
Florida	141,000	118,000	13,400	NA
Georgia	127,000	120,000	1,040	NA
Idaho	46,200	40,000	1,620	NA
Illinois	646,000	552,000	28,500	NA
Indiana	361,000	295,000	14,800	NA
Iowa	479,000	429,000	4,160	NA
Kansas	32,300	25,400	9,120	NA
Kentucky	138,000	109,000	8,780	NA
Louisiana	83,500	71,000	6,920	NA
Maine	4,880	3,450	347	NA
Maryland	24,100	21,300	1,530	NA
Massachusetts	2,350	12,600	8,010	NA
Michigan	189,000	155,000	9,110	NA
Minnesota	345,000	272,000	9,330	NA
Mississippi	46,100	23,500	254	NA
Missouri	320,000	240,000	2,630	NA
Montana	20,400	17,900	96	NA
Nebraska	60,800	48,400	1,960	NA
Nevada	558	424	158	NA
New Hampshire	357	497	108	NA
New Jersey	7,770	6,370	1,290	NA
New Mexico	18,800	9,130	35,600	NA
New York	56,800	47,000	3,700	NA
North Carolina	130,000	100,000	837	NA
North Dakota	38,100	37,600	24	NA
Ohio	315,000	262,000	105,000	NA
Oklahoma	36,400	32,200	5,640	NA
Oregon	43,900	34,100	201	NA
Pennsylvania	59,600	52,000	8,290	NA
Rhode Island	--	--	24	NA

See footnotes at end of table.

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TABLE 3—Continued

SALES OF NORTH AMERICAN MURIATE OF POTASH, BY STATE OF DESTINATION[1]

(Metric tons of K_2O equivalent)

State	Agricultural potash		Nonagricultural potash	
	2004	2005	2004	2005
South Carolina	61,000	52,700	98	NA
South Dakota	23,100	30,300	200	NA
Tennessee	148,000	116,000	10,600	NA
Texas	114,000	102,000	67,400	NA
Utah	2,620	2,670	82,200	NA
Vermont	2,870	2,200	30	NA
Virginia	87,600	77,200	1,320	NA
Washington	46,200	37,800	565	NA
West Virginia	1,670	1,360	970	NA
Wisconsin	205,000	225,000	97,200	NA
Wyoming	2,570	2,250	5,010	NA
Total	4,740,000	3,990,000	875,000	923,000

NA Not available. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: Potash and Phosphate Institute.

TABLE 4

SALES OF NORTH AMERICAN MURIATE OF POTASH TO U.S. CUSTOMERS, BY GRADE[1]

(Thousand metric tons of K_2O equivalent)

Grade	2004	2005
Agricultural:		
Standard	173	124
Coarse	2,390	1,130
Granular	1,710	2,280
Soluble	463	455
Total	4,740	3,990
Nonagricultural:		
Soluble	699	NA
Other	176	NA
Total	875	923
Grand total	5,610	4,910

NA Not available.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: Potash & Phosphate Institute.

TABLE 5

PRICES OF U.S. POTASH, BY TYPE AND GRADE[1, 2]

(Dollars per metric ton of K_2O equivalent)

Type and grade	2004			2005		
	January-June	July-December	Yearly average	January-June	July-December	Yearly average
Muriate, 60% K_2O minimum:						
Standard	170	190	180	185	275	230
Granular	195	225	210	300	305	300

[1]Average prices, free on board mine, based on sales.

[2]Data rounded to nearest $5.

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TABLE 6
U.S. EXPORTS OF POTASH, BY TYPE[1]

	Approximate average K_2O equivalent content (percentage)	Quantity (metric tons)	
		Gross weight	K_2O equivalent[e]
2004:			
Potassium chloride, all grades	61	184,000 [r]	112,000 [r]
Potassium sulfate	51	68,100	34,700
Potassium magnesium sulfate	22	383,000	84,200
Potassium nitrate	45	5,390	2,430
Total	XX	640,000 [r]	233,000 [r]
2005:			
Potassium chloride, all grades	61	136,000	83,200
Potassium sulfate	51	72,100	36,800
Potassium magnesium sulfate	22	356,000	78,400
Potassium nitrate	45	3,910	1,760
Total	XX	569,000	200,000

[e]Estimated. [r]Revised. XX Not applicable.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau, as adjusted by the U.S. Geological Survey.

TABLE 7
U.S. EXPORTS OF POTASH, BY COUNTRY[1]

(Metric tons of product)

Country	Potassium chloride		Potassium sulfates, all grades[2]		Potassium nitrate		Total	
	2004	2005	2004	2005	2004	2005	2004	2005
Argentina	19	--	5,490	3	--	--	5,510	3
Australia	--	18	14,100	24,800	--	--	14,100	24,800
Barbados	1,150	1,100	180	157	--	--	1,330	1,260
Belize	1,940	--	6	36	--	--	1,950	36
Brazil	--	25,000	5,410	10,500	7	--	5,420	35,500
Canada	4,260	2,060	74,000	76,200	1,540	846	79,800	79,100
Chile	86	--	29,900	29,800	--	--	30,000	29,800
China	2 [r]	--	25,600	28,000	20	10	25,700	28,000
Colombia	126	72	24,100	33,300	4	3	24,300	33,400
Costa Rica	1,980	6,000	39,300	40,000	--	--	41,300	46,000
Côte d'Ivoire	--	--	--	3,000	--	--	--	3,000
Czech Republic	201	320	--	--	--	--	201	320
Dominican Republic	21,100	4,000	14,900	6,000	4	5	36,000	10,000
Ecuador	7,020	18	5,500	9,010	--	--	12,500	9,030
El Salvador	4,200	6,200	2,100	2	--	--	6,300	6,200
Guatemala	9,930	6	6,810	3,000	--	--	16,700	3,010
Gutana	--	2,500	--	--	--	--	--	2,500
Honduras	4,220	--	11,000	8,510	--	--	15,300	8,510
Indonesia	--	--	5,500	--	--	--	5,500	--
India	2	--	--	--	--	2,150	2	2,150
Israel	--	--	--	935	6	--	6	935
Jamaica	10,600	--	--	--	7	--	10,600	--
Japan	5,530 [r]	40	49,600	46,700	--	1	55,100 [r]	46,700
Korea, Republic of	2 [r]	1	93	5,070	16	71	111 [r]	5,150
Malaysia	--	--	7,900	--	--	--	7,900	--
Martinique	8,300	13,900	805	3,560	--	--	9,110	17,500
Mexico	60,300	57,400	70,100	61,500	2,640	377	133,000	119,000

See footnotes at end of table.

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TABLE 7—Continued
U.S. EXPORTS OF POTASH, BY COUNTRY[1]

(Metric tons of product)

Country	Potassium chloride		Potassium sulfates, all grades[2]		Potassium nitrate		Total	
	2004	2005	2004	2005	2004	2005	2004	2005
New Zealand	--	--	5,010	--	--	32	5,010	32
Nicaragua	2,670	4,400	1,400	3,750	--	--	4,070	8,150
Panama	12,600	10,400	1,690	1,750	--	--	14,200	12,200
Peru	30	20	14,200	20,000	--	--	14,200	20,000
Russia	--	274	--	--	6	--	6	274
Saudi Arabia	--	617	210	--	396	--	606	617
South Africa	--	--	3,260	--	--	--	3,260	--
Suriname	800	--	718	--	--	--	1,520	--
Thailand	485 r	258	--	--	--	--	485 r	258
Trinidad and Tobago	1,500	1,200	--	4	--	--	1,500	1,200
Venezuela	24,100	2	30,600	12,200	--	--	54,700	12,200
Other	685 r	471	1,160 r	806	751 r	412	2,600 r	1,690
Total	184,000 r	136,000	451,000	429,000	5,390	3,910	640,000 r	569,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes potassium magnesium sulfate.

Source: U.S. Census Bureau, as adjusted by the U.S. Geological Survey.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF POTASH, BY TYPE[1]

	Approximate average K_2O equivalent content (percentage)	Quantity (metric tons)		Value (thousands)	
		Gross weight	K_2O equivalent[e]	Customs	C.i.f.[2]
2004:					
Potassium chloride[3]	61	7,880,000	4,810,000	$686,000	$709,000
Potassium sulfate	51	107,000	54,500	21,200	24,800
Potassium nitrate	45	116,000	52,400	32,900	36,900
Potassium sodium nitrate mixture	14	41,900	5,870	11,800	14,800
Total	XX	8,140,000	4,920,000	751,000	785,000
2005:					
Potassium chloride[3]	61	7,880,000	4,810,000	1,100,000	1,160,000
Potassium sulfate	51	106,000	53,900	23,400	27,700
Potassium nitrate	45	120,000	54,000	40,700	46,200
Potassium sodium nitrate mixture	14	5,700	798	1,750	2,250
Total	XX	8,110,000	4,920,000	1,170,000	1,240,000

[e]Estimated. XX Not applicable.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Cost, insurance, and freight.

[3]Contains imports listed under Harmonized Tariff Schedule of the United States code 3104.10.0000.

Source: U.S. Census Bureau, as adjusted by the U.S. Geological Survey.

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TABLE 9

U.S. IMPORTS FOR CONSUMPTION OF POTASH, BY COUNTRY[1]

Country	Potassium chloride (metric tons)		Potassium sulfate (metric tons)		Potassium nitrate (metric tons)		Potassium sodium nitrate (metric tons)		Total Quantity (metric tons)		Total Value (thousands) Customs		Total Value (thousands) C.i.f.[2]	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Australia	--	2	--	--	--	--	--	--	--	2	--	$3	--	$3
Belarus	493,000	436,000	--	--	--	--	--	--	493,000	436,000	$58,500	73,500	$67,200	82,400
Belgium	11	--	10,400	5,520	--	7	--	--	10,400	5,520	2,440	1,530	2,710	2,250
Cameroon	--	17	--	--	--	--	--	--	--	17	--	6	--	6
Canada	7,280,000	7,030,000	18,300	13,000	--	--	1,240	1,760	7,300,000	7,040,000	616,000 r	972,000	628,000 r	1,000,000
Chile	166	--	11,400	13,300	104,000	81,500	16,500	--	115,000	94,800	32,800	30,500	36,500	32,700
China	--	--	--	--	36	18	--	--	36	18	16	14	22	16
Denmark	--	--	--	--	2,250	--	38	--	2,250	--	668	--	973	--
France	--	--	202	163	--	--	--	--	202	163	222	190	258	215
Germany	12,500	29,800	66,400	72,400	1,870	2,500	--	--	80,800	105,000	13,600	20,100	17,000	24,200
India	--	1	2	4	57	393	--	--	59	398	47	134	51	144
Israel	226	5,720	--	--	7,350	34,300	24,100	3,860	7,570	43,900	12,000	14,000	15,000	17,800
Italy	--	--	--	36	--	--	--	--	--	36	--	43	--	50
Japan	--	--	137	234	1,020	1,090	--	--	1,160	1,320	445	554	506	646
Mexico	--	39	--	--	--	7	--	--	--	46	--	27	--	28
Netherlands	130	165	--	--	--	--	--	1	130	166	2	14	3	15
Poland	--	--	--	--	198	160	--	--	198	160	73	88	83	108
Russia	91,500	382,000	--	--	--	--	--	44	91,500	382,000	8,720	63,300	11,100	75,000
Slovakia	--	19	--	--	--	--	--	--	--	19	--	3	--	3
Spain	--	--	--	1,020	13	--	--	--	--	1,020	12	112	15	117
United Kingdom	90	180	--	--	--	2	49	37	90	219	160	286	229	314
Total	7,880,000	7,880,000	107,000	106,000	116,000	120,000	41,900	5,700	8,140,000	8,110,000	751,000 r	1,170,000	785,000 r	1,240,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Cost, insurance, and freight.

Source: U.S. Census Bureau, as adjusted by the U.S. Geological Survey.

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TABLE 10

MARKETABLE POTASH: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons of K_2O equivalent)

Country	2001	2002	2003	2004	2005[e]
Belarus[e]	3,700	3,800	4,230	4,600 [r]	4,844 [3]
Brazil	319	337	416 [r]	403 [r]	405
Canada	8,237	8,515 [r]	9,093 [r]	10,114 [r]	10,120 [3]
Chile[e]	390	350	370	370 [r]	370
China[e]	385	450	500	551	600
France[e]	244	130	--	--	--
Germany	3,549 [r]	3,472 [r]	3,563 [r]	3,626 [r]	3,600
Israel	1,770	1,920	1,960	2,060 [e]	2,060
Jordan	1,180	1,170	1,230	1,230 [e]	1,230
Russia[e]	4,300	4,400	4,740	5,000	5,500
Spain[e]	471	407	510	500	500
Ukraine[e]	75	60	60	50	65
United Kingdom[e]	532	540	620	600	600
United States[e, 4]	1,200	1,200	1,100	1,300	1,200
Total	26,400 [r]	26,800 [r]	28,400	30,400 [r]	31,100

[e]Estimated. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through April 24, 2006.

[3]Reported figure.

[4]Rounded to within 100,000 metric tons to avoid disclosing proprietary data.

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PUMICE AND PUMICITE

By Alan Founie

Survey data and tables were prepared by Virginia C. Harper, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

In 2005, U.S. pumice and pumicite production was 1.27 million metric tons (Mt). This was a decrease of 15% compared with 2004, which had been a record high year for U.S. pumice production. The decrease in production tonnage was offset by a 57% increase in the overall value of production to $39 million in 2005 from $25 million in 2004. This rise in value was attributed to a large increase in the average unit value of pumice building blocks, which account for 70% of domestic consumption of pumice and pumicite. The apparent consumption of pumice and pumicite in the United States in 2005 was 1.49 Mt, a decrease of 20% compared with that of 2004. Imports decreased by 40% to 240,000 metric tons (t). Exports of 21,000 t represented a decrease of about 22% compared with exports of 27,000 t in 2004 (table 1).

The main use for pumice continued to be as an aggregate in lightweight building blocks and assorted building products. Other major applications for pumice and pumicite included abrasives, absorbents, concrete aggregate and admixture, filter aids, horticulture (including landscaping), stonewashing of denim, and as a traction enhancer for tires. Imports were used primarily as a lightweight aggregate, but a small percentage of pumice imports was used in abrasive applications.

Domestic Data Coverage

Domestic production data for pumice and pumicite were developed by the U.S. Geological Survey (USGS) from an annual voluntary survey of U.S. pumice- and pumicite-producing sites and company operations. The canvass for 2005 covered 16 companies with 16 active operations that produced and sold or used all the domestic pumice and pumicite in the United States. The eight companies that responded represented about 76% of the 1.27 Mt produced. Sold and used data for seven of the eight companies that did not respond to the 2005 survey were estimated; the remaining nonrespondent had abandoned its operation. Data are rounded to no more than three significant digits. All percentages in this report were computed based on unrounded data.

Description and Terminology

Pumice is a low density, porous, vesicular, glassy volcanic rock that forms during explosive eruptions. It resembles a sponge because it consists of a network of gas bubbles frozen amidst fragile volcanic glass and minerals. Pumicite is a term for material made entirely of pumice, but the term is commercially used for material of smaller particle size (typically less than 4 millimeters). All types of magma, including andesite, basalt, dacite, and rhyolite, will form pumice. Scoria is another term used for vesicular glassy lava rock, though it usually refers to dark rock of basaltic to andesitic composition and commercial practice is to use the term scoria for larger fragments (greater than 2.5 centimeters) (Presley, 2006, p. 743). Rocks called scoria are typically dark gray to black in color and denser than those termed pumice, and the term scoria has been used for dark pumice from basaltic rocks. In the past (and still locally) the terms pumice, pumicite, scoria, volcanic ash, and volcanic cinder, are used interchangeably. Pumice is the preferred term. Pumice and pumicite production in this report includes all material reported and sold as pumice or pumicite and may include some volcanic ash. Scoria used as aggregate is reported in the crushed stone reports and has not been included here.

Production

U.S. pumice and pumicite production of 1.27 Mt was valued at $39 million. In 2005, 28% of domestic pumice and pumicite production came from Arizona followed closely by Oregon with 27%. Other States that produced pumice and pumicite, in descending order of production, were Idaho, New Mexico, California, and Kansas.

Pumice is usually extracted by simple open pit methods using rippers, bulldozers, and front-end loaders. Processing is usually just drying, crushing, and screening, though some abrasive grades may require fine grinding and classification and blocks may be sawn into shapes and sizes.

Consumption

In 2005, more than 1 Mt of the pumice and pumicite produced in the United States went into the building and decorative blocks use category (table 2). This was a 12% decrease from 2004; this, however, was still the leading end-use category, consuming 82% of production, up from 79% in 2004. Pumice used for horticultural and landscaping purposes decreased by 39% to 143,000 t in 2005 from a total of 236,000 t in 2004 and accounted for 11% of consumption. Pumice use as an abrasive was up slightly to 41,000 t in 2005 from 40,000 t in 2004 and accounted for 3% of consumption. Pumice and pumicite used for concrete admixture and aggregate also rose slightly in 2005 to 30,000 t from 29,000 t in 2004 and accounted for 2% of consumption. There are many substitutes for pumice as a concrete additive or aggregate. The amount of the pumice reported sold or used by several low-volume markets or for unreported uses grouped in the "other" category rose in 2005 to 15,000 t from 6,000 t in 2004 and accounted for about 1% of consumption. This may have been owing to producers being less precise in categorizing sales on the survey forms rather than to a real increase in consumption for "other" uses. "Other" uses accounted for 1% of consumption and included absorbent

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(including pet litter), diluent, engineered fill, filter aids, in geotechnical uses, in laundries (stone-washing), in pottery clays, and for other unspecified uses.

Prices

The average prices reported for pumice and pumicite varied greatly by use compared with the average price for all uses in 2005. The overall average prices reported of all pumice and pumicite products increased dramatically to $31.00 per metric ton in 2005 compared with $16.80 per ton in 2004, an increase of 85%. The price change was the result of increases in the unit values of pumice building blocks and pumice as a soil additive for horticultural and landscaping, the two leading uses of pumice in the United States. The value of blocks manufactured from pumice caused the unit value of the building block and decorative use category to increase by 162% to $25.52 per ton in 2005 from $9.75 per ton in 2004. The average price for pumice and pumicite used for horticultural and landscaping increased by 15% to $16.30 per ton in 2005 from $14.23 per ton in 2004. The average price in 2005 for pumice and pumicite used for abrasives was $228.42 per ton; for concrete admixture and aggregates, $21.42 per ton; and for other uses, $32.04 per ton (table 2). The increase in pumice product prices reflected the price increase in most construction materials in 2005 owing to increased demand.

Foreign Trade

Exports of pumice decreased to about 21,000 t in 2005 with a value of $7.5 million. Countries that imported from the United States in descending order of tonnage shipped, were Canada (34%), Mexico (9%), Hong Kong (8%), Germany (8%), China (7%), the United Kingdom (6%), Brazil (4%), India (4%), Japan (4%), Malaysia (3%), Suriname (3%), Taiwan (2%), Thailand (2%), and Singapore (2%). The remaining 4% of exports went to 22 other countries in Asia, Central America, Europe, the Middle East, Oceania, and South America.

Imports in 2005 decreased by 40% to 240,000 t compared with 402,000 t in 2004. By volume, most imports of pumice and pumicite were for lightweight aggregate in construction-related uses with smaller amounts used in a range of abrasives and for the stonewashing of denim. Ninety-seven percent of imported pumice was from Greece and Italy (table 3). All imports from Greece and the majority of imports from Italy were thought to have been shipped to the United States by a single company. Greece supplied 188,000 t, accounting for 78% of pumice imports in 2005 and remained the leading source of pumice imports even though Greek sources supplied 24% less than in 2004. Imports from Italy accounted for 45,000 t (19%) of total imports, down from 147,000 t in 2004. Most of the remaining 3% of pumice imports was supplied by Turkey, although 16 other countries also exported small amounts of pumice and pumicite to the United States in 2005.

World Review

The USGS estimated world pozzolan and pumice (and related materials) production to be 17.5 Mt in 2005, slightly less than in 2004 (table 4). Most of the data published were provided by official government agencies in each country. Significant revisions of data are sometimes reported by these agencies, usually without supporting explanations. Italy remained the leading producer of pumice and pozzolan with production estimated to be 4.6 Mt. Strictly defined, pozzolans are volcanic tuffs of the type found near Pozzuoli in southern Italy. However, internationally, the term pozzolan is commonly applied to any of the many silicious materials, such as diatomaceous earth, fly ash, opaline shale, pumicite, tuff, and volcanic ash, which when added to the cement in concrete improve the strength or other properties of the concrete. Greece was the second ranked producer in 2005 with production estimated to be 2.25 Mt. Chile was third with 1.55 Mt, and the United States, with 1.27 Mt, was the fourth ranked producer in 2005. Other countries with production of 1.0 Mt or more of pozzolan, pumice, and related materials were Iran and Turkey. In addition, 29 other countries were known to have produced pumice.

Pumice is used more extensively as a building material outside the United States, which helps to explain the large global production and sales of pumice. In Europe, for example, basic home construction uses significantly less gypsum sheetrock because stone and concrete are the preferred building materials. Prefabricated lightweight concrete walls often are produced and shipped to construction locations. Because of their lightweight, strength, and cementitious properties, pumice and pumicite perform very well in European-style construction.

Outlook

U.S. consumption of pumice and pumicite in 2006 is expected to rise slightly along with the popularity and use of artificial blocks made with pumice for construction and decoration. Imports and exports are also expected to rise slightly in 2006. Worldwide consumption of pumice is expected to be about the same as in 2005.

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TABLE 1

SALIENT PUMICE AND PUMICITE STATISTICS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

	2001	2002	2003	2004	2005
United States:					
Sold and used by producers:					
Quantity	919	956	870	1,490	1,270
Value[2]	19,700	19,800	21,900	25,000	39,300
Average value dollars per metric ton	21.41	20.69	25.20	16.80	30.99
Exports[3]	27	30	26	27	21
Imports for consumption[3]	379	360	367	402	240
Apparent consumption[4]	1,270	1,290	1,210	1,870	1,490
World, production, pumice and related volcanic materials	15,600 r	16,200 r	16,600 r	17,700 r	17,500 e

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits, except average value.

[2]Free on board mine and/or mill.

[3]Source: U.S. Census Bureau.

[4]Production plus imports minus exports plus adjustments for Government and industry stock changes.

TABLE 2

PUMICE AND PUMICITE SOLD AND USED BY PRODUCERS IN THE UNITED STATES, BY USE[1]

	2004			2005		
Use	Quantity (thousand metric tons)	Value (thousands)	Average unit value	Quantity (thousand metric tons)	Value (thousands)	Average unit value
Abrasives[2]	40	$8,590	$216.83	41	$9,340	$228.42
Building block, includes decorative block	1,180	11,500	9.75	1,040	26,500	25.52
Concrete admixture and aggregate	29	1,240	43.05	30	648	21.42
Horticulture and landscaping	236	3,360	14.23	143	2,340	16.30
Other[3]	6	338	53.32	15	486	32.04
Total or average	1,490	25,000	16.80	1,270	39,300	31.00

[1]Data are rounded to no more than three significant digits, except average unit value; may not add to totals shown.

[2]Includes cleaning and scouring compounds.

[3]Includes absorbent, diluents, fill, filter aids, laundries, pottery, and other unspecified uses.

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TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF PUMICE,
BY CLASS AND COUNTRY[1]

Country	Crude or unmanufactured Quantity	Crude or unmanufactured Value	Wholly or partly manufactured Quantity	Wholly or partly manufactured Value
2004:				
Greece[2]	247	7,530	(3)	617
Italy[2]	147	22,000	(3)	39
Turkey	7	1,510	--	--
Other[4]	(3)	355	(3)	3,000
Total	401	31,400	1	3,660
2005:				
Greece[2]	188	11,500	(3)	3,400
Italy[2]	45	17,200	(3)	507
Turkey[2]	4	1,020	--	--
Other[5]	2	2,080	(3)	1,850
Total	239	31,800	1	5,750

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Quantity of crude or unmanufactured pumice derived from the Journal of Commerce Port Import/Export Reporting Service data.

[3]Less than ½ unit.

[4]Includes Argentina, Austria, China, Ecuador, Germany, Hong Kong, Indonesia, Japan, the Republic of Korea, Mexico, Malaysia, Poland, Russia, Taiwan, and the United Kingdom.

[5]Includes Austria, China, France, Germany, Hong Kong, India, Indonesia, Japan, the Republic of Korea, Malaysia, Mexico, Poland, Taiwan, Thailand, and the United Kingdom.

Source: U.S. Census Bureau.

TABLE 4
PUMICE AND RELATED MATERIALS: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Algeria, pozzolan[e]	421,238 [4]	451,000	500,000	508,000 [r]	494,000 [4]
Argentina, pumice	2,097	3,070	3,531	9,188 [r]	9,000
Austria, trass[e]	5,000	5,000	5,000	5,000	5,000
Burkina Faso[e]	10,000	10,000	10,000	10,000	10,000
Cameroon, pozzolan[e]	600,000	620,000	600,000	600,000	600,000
Cape Verde, pozzolan	-- [r]	-- [r]	-- [r]	-- [r]	--
Chile:					
Pozzolan	785,000	826,000	825,000	750,000 [r]	750,000
Pumice	--	354	417,023	785,033 [r]	800,000
Costa Rica[e]	8,000	8,000	8,000	8,000	8,000
Croatia, volcanic tuff[e]	42,000	41,000	29,000	30,000	30,000
Dominica, pumice and volcanic ash[e]	100,000	100,000	100,000	100,000	100,000
Ecuador:					
Pozzolan	373,023 [r]	519,090	190,747 [r]	190,000 [r, e]	190,000
Pumice	373,023	130,000	271,000 [r]	298,000 [r]	300,000

See footnotes at end of table.

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TABLE 4—Continued

PUMICE AND RELATED MATERIALS: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
El Salvador, pozzolan	265,458	279,389	294,871	222,826	220,000
Eritrea, pumice	195	212	50 [r]	439 [r]	440
Ethiopia[5]	180,000 [r, e]	210,000 [r, e]	218,676 [r]	270,994 [r]	350,000
France, pozzolan and lapilli[e]	450,000	450,000	450,000	450,000	450,000
Germany, pumice, marketable[e]	124,000 [r]	43,000 [r]	-- [r]	-- [r]	--
Greece:					
Pozzolan	1,308,131 [r]	1,291,198 [r]	1,383,546 [r]	1,400,000 [r, e]	1,400,000
Pumice[e]	850,000	850,000	850,000	850,000	850,000
Guadeloupe, pumice[e]	210,000	210,000	210,000	210,000	210,000
Guatemala, pumice	264,322	377,403	273,933	226,459 [r]	230,000
Honduras, pozzolan[e]	189,999 [4]	190,000	190,000	190,000	190,000
Iceland:					
Pumice	70,751 [r]	56,478 [r]	50,193 [r]	50,000 [e]	50,000
Scoria[e]	1,000 [r]	1,000 [r]	1,000 [r]	1,000	1,000
Iran	843,912	1,181,543	1,200,000 [e]	1,200,000 [e]	1,200,000
Italy:[e]					
Pozzolan	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000
Pumice and pumiceous lapilli	600,000	600,000	600,000	600,000	600,000
Macedonia, volcanic tuff[e]	50,000	50,000	50,000	50,000	50,000
Martinique, pumice[e]	130,000	130,000	130,000	130,000	130,000
New Zealand[e]	68,000	203,700 [4]	204,000	200,000	200,000
Saudi Arabia, pozzolan[e]	150,000	150,000	160,000	160,000	160,000
Serbia and Montenegro, volcanic tuff[e]	100,000	100,000	100,000	100,000	100,000
Slovenia, volcanic tuff[e]	40,000	40,000	40,000	40,000	40,000
Spain, including Canary Islands[e]	600,000	600,000	600,000	600,000	600,000
Syria, volcanic tuff[e]	650,000 [r]	650,000 [r]	650,000 [r]	650,000 [r]	650,000
Tanzania, pozzolanic materials	41,468	52,000	105,910 [r]	152,679 [r]	160,000
Turkey	754,052	820,347	895,616	1,035,975 [r]	1,000,000
Uganda, pozzolanic materials	22,782	12,388	65,587	134,644 [r]	140,000
United States, pumice, sold and used by producers	919,000	956,000	870,000	1,490,000	1,270,000 [4]
Grand total	15,600,000 [r]	16,200,000 [r]	16,600,000 [r]	17,700,000 [r]	17,500,000
Of which:					
Pumice	2,940,000 [r]	2,760,000 [r]	3,080,000 [r]	4,050,000 [r]	3,850,000
Pozzolan	8,160,000 [r]	8,390,000 [r]	8,320,000 [r]	8,310,000 [r]	8,300,000
Trass and scoria	6,000 [r]	6,000 [r]	6,000 [r]	6,000	6,000
Volcanic tuff	882,000 [r]	881,000 [r]	869,000 [r]	870,000 [r]	870,000
Unspecified	3,610,000 [r]	4,180,000 [r]	4,290,000 [r]	4,470,000 [r]	4,520,000

[e]Estimated. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through April 24, 2006.

[3]Pumice and related materials also are produced in a number of other countries, including China, Japan, Mexico, and the Commonwealth of Independent States, but available information is inadequate for the formulation of reliable estimates of output levels.

[4]Reported figure.

[5]Data are for year ending July 7 of that stated.

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RARE EARTHS

By James B. Hedrick

Domestic survey data and tables were prepared by Nicholas A. Muniz, statistical assistant, the world production tables were prepared by Regina R. Coleman, international data coordinator, and the figure was designed by Robert M. Callaghan, geographic information specialist.

In 2005, world rare-earth production was primarily from the mineral bastnäsite. Rare earths were not mined in the United States in 2005; however, the mine and plant at Mountain Pass, CA, was kept on care-and-maintenance status. Rare-earth ores were primarily supplied by China, with lesser amounts mined in Brazil, India, and Russia. Domestic stocks of previously produced bastnäsite concentrates, intermediate rare-earth concentrates, and separated products were available for purchase from Molycorp, Inc. at Mountain Pass. Consumption was estimated to have decreased as did imports of individual rare-earth compounds and mixed rare-earth compounds. U.S. imports of cerium compounds, ferrocerium and pyrophoric compounds, rare-earth chlorides, rare-earth metals and alloys, and yttrium compounds increased.

Domestic use of scandium increased slightly in 2005. Overall consumption of the commodity remained small. Demand was primarily for aluminum alloys used in baseball and softball bats. Scandium alloys, compounds, and metals were used in analytical standards, metallurgical research, and sports equipment. Minor amounts of high-purity scandium were used in semiconductors and specialty lighting.

Yttrium consumption decreased by about 6% in 2005 compared with that of 2004, according to data from the Port Import Export Reporting Service (PIERS) database of Commonwealth Business Media, Inc. (undated §[1]). Yttrium was used primarily in lamp and cathode-ray tube phosphors; lesser amounts were used in structural ceramics and oxygen sensors.

The rare earths are a moderately abundant group of 17 elements comprising the 15 lanthanides, scandium, and yttrium. The elements range in crustal abundance from cerium, the 25th most abundant element of the 78 common elements in the Earth's crust at 60 parts per million (ppm), to thulium and lutetium, the least abundant rare-earth elements at about 0.5 ppm (Mason and Moore, 1982, p. 46). In rock-forming minerals, rare earths typically occur in compounds as trivalent cations in carbonates, oxides, phosphates, and silicates.

The lanthanides comprise a group of 15 elements with atomic numbers 57 through 71 that include the following in order of atomic number: lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium. Cerium, which is more abundant than copper (whose average concentration in the Earth's crust is 50 ppm), is the most abundant member of the group at 60 ppm, followed, in decreasing order, by yttrium at 33 ppm, lanthanum at 30 ppm, and neodymium at 28 ppm. Thulium and lutetium, the least abundant of the lanthanides at 0.5 ppm, occur in the Earth's crust in higher concentrations than antimony, bismuth, cadmium, and thallium.

Scandium, whose atomic number is 21, is the lightest rare-earth element. It is the 31st most abundant element in the Earth's crust, with an average crustal abundance of 22 ppm. Scandium is a soft, lightweight, silvery-white metal, similar in appearance and weight to aluminum. It is represented by the chemical symbol Sc and has one naturally occurring isotope. Although its occurrence in crustal rocks is greater than lead, mercury, and the precious metals, scandium rarely occurs in concentrated quantities because it does not selectively combine with the common ore-forming anions.

Yttrium, whose atomic number is 39, is chemically similar to the lanthanides and often occurs in the same minerals as a result of its similar ionic radius. It is represented by the chemical symbol Y and has one naturally occurring isotope. Yttrium's average concentration in the Earth's crust is 33 ppm and is the second most abundant rare earth in the Earth's crust. Yttrium is a bright silvery metal that is soft and malleable, similar in density to titanium.

The elemental forms of rare earths are iron gray to silvery lustrous metals that are typically soft, malleable, ductile, and usually reactive, especially at elevated temperatures or when finely divided. Melting points range from 798° C for cerium to 1,663° C for lutetium. The unique properties of rare earths are used in a wide variety of applications. The principal economic rare-earth ores are the minerals bastnäsite, loparite, and monazite and lateritic ion-adsorption clays (table 2).

Production

In 2005, Molycorp, Inc. (a wholly owned subsidiary of Unocal Corporation), remained open on a care-and-maintenance basis and sold from its stockpile of bastnäsite concentrates, intermediate concentrates, and separated compounds previously processed at its open pit operations at Mountain Pass. On August 10, Unocal Corporation (Molycorp's parent company) merged with Chevron Corporation. The merger created the world's fourth largest publicly traded energy company (Unocal Corporation, 2005).

Although Molycorp was not actively mining rare earths, the sales operation remained open, and several lanthanide products were packaged, sold, and shipped. Substantial stocks of lanthanide concentrates and intermediate and refined compounds were available. Lanthanide products available in 2005 from Molycorp were bastnäsite concentrate, cerium nitrate, lanthanum chloride, lanthanum hydrate, lanthanum-rich nitrate, and the oxides of cerium, erbium, europium, gadolinium, praseodymium, samarium, and yttrium.

Three companies processed intermediate rare-earth compounds to lanthanides in 2005. Grace Davison (a subsidiary of W.R. Grace & Co.) processed intermediate rare-earth compounds to produce cerium- and lanthanum-rich compounds used in making fluid-cracking catalysts for the petroleum industry and processed cerium and zirconia compounds

[1]References that include a section mark (§) are found in the Internet References Cited section.

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for automotive catalysts and catalyst supports. W.R. Grace announced an 8% increase in the prices of its fluid cracking catalysts and fluid cracking catalyst additives in January. The increase was required to keep pace with increased fuel and material costs (W.R. Grace & Co., 2005). At yearend 2005, Grace reported increased sales revenues based on increased demand for fluid cracking catalysts, especially those used to produce clean fuels (W.R. Grace & Co., 2006).

Santoku America, Inc. (a subsidiary of Santoku Corporation of Japan) produced rare-earth magnet and rechargeable battery alloys at its operations in Tolleson, AZ. Santoku America produced both types of high-strength permanent magnets, namely neodymium-iron-boron (NIB) and samarium-cobalt magnets. For the rechargeable battery industry, Santoku produced nickel-metal hydride (NiMH) alloys that incorporate specialty rare-earth mischmetals. The plant also produced a full range of high-purity rare-earth metals in cast and distilled forms, foils, and sputtering targets, including scandium and yttrium. The principal domestic producer of NIB magnet alloys was Santuko America. Leading U.S. producers of rare-earth magnets were Electron Energy Corporation, Landisville, PA; Hitachi Metals North Carolina, China Grove, NC; and VAC Magnetics Corporation [a subsidiary of Vacuumschmelze GMBH & Co. KG (a division of Morgan Crucible Company plc.)], Elizabethtown, KY. Hitachi Magnetics, closed its rare-earth magnet plant in Edmore, MI, in 2005 as a result of low-cost production from China (Associated Press, 2005§). Demand for rare earths used in NiMH batteries increased in 2005 as did overall demand for rechargeable batteries. Rechargeable batteries are used in camcorders, cellular telephones, PDAs, portable computers, and other portable devices. The principal world markets for rechargeable batteries are laptop computers and cellular telephones.

Santoku (33%) continued its joint venture Anan Kasei Ltd. with Rhodia Electronics and Catalysis, Inc. (67%). The joint-venture operations, located in Anan, Japan, produced ceramic capacitors; ferrites; fuel additive emission-reduction catalysts; microwave filters; phosphors used in CRTs, lamps, and PDP television; polishing compounds for electronic components, hard disks, lenses, mirrors, ophthalmic glass, and semiconductors; rare-earth-base nontoxic colorants and coatings for plastics; and three-way catalytic converter catalysts (Rhodia Japan—Anan Kasei Ltd., undated §).

On Septermber 9, Rhodia announced it would release its third generation of rare-earth-based additives for regeneration of diesel particulate filters (DPF). The enhanced EOLYS™ G3 fuel additive catalyst for diesel engines facilitates the regeneration of DPF with improved durability, faster regeneration, and a lower volume of additive (Rhodia Electronics and Catalysis Inc., 2005§). Rhodia also produced rare-earth-containing catalysts for automotive emission applications for gasoline engines. Rhodia's other operations produced finished rare-earth products from imported materials at its plant in Freeport, TX, and produced high-purity rare earths at its separation plant in La Rochelle, France. Additional rare-earth capacity was operated through Anan Kasei in Kobe, Japan. In 2005, Rhodia reported sales by market segment to be 56% electronics, 37% catalysis, and 7% new markets.

Two scandium processors operated in 2005. High-purity products were available in various grades, with scandium oxide having up to 99.999% purity. Boulder Scientific Co. processed scandium at its Mead, CO, operations. It refined scandium primarily from imported oxides to produce high-purity scandium compounds, including carbide, chloride, diboride, fluoride, hydride, nitride, oxalate, and tungstate.

Scandium also was purified and processed from imported oxides at Aldrich-APL, LLC in Urbana, IL, to produce high-purity scandium compounds, including anhydrous and hydrous chloride, fluoride, iodide, and oxide. The company also produced high-purity scandium metal.

All commercially produced purified yttrium was derived from imported compounds. The principal source was China.

Consumption

Data on domestic rare-earth consumption were developed by surveying various processors and manufacturers, evaluating import and export data, and analyzing U.S. Government stockpile shipments. Domestic apparent consumption of rare earths decreased in 2005 compared with that of 2004.

In 2005, yttrium consumption was estimated to have decreased to 582 t from 619 t in 2004. Yttrium information was based on data retrieved from the PIERS database. Yttrium compounds and metal were imported from several sources in 2005. Yttrium compounds and metal were imported from China (90.7%), Japan (3.39%), Belgium (3.37%), Austria (1.66%), and Hong Kong (0.88%). The estimated use of yttrium, based on imports, was primarily in lamp and cathode-ray tube phosphors, ceramics, and electronics (94.0%), and in specialty alloys (6.0%) (Commonwealth Business Media, Inc., undated §).

Stocks

All U.S. Government stocks of rare earths in the National Defense Stockpile (NDS) were shipped in 1998. Periodic assessments of the national defense material requirements may necessitate the inclusion of rare earths, including scandium and yttrium, in the NDS at a future date.

Prices

The prices of rare-earth materials either increased or were essentially unchanged in 2005 compared with those of 2004. The following estimates of prices were based on trade data from various sources or were quoted by rare-earth producers. All rare-earth prices remained nominal and subject to change without notice. The competitive pricing policies in effect in the industry caused most rare-earth product prices to be quoted on a daily basis from the producers and processors. The average price of imported rare-earth chloride was $2.37 per kilogram in 2005, a decrease from $2.41 per kilogram in 2004. Imported rare-earth metal prices averaged $6.68 per kilogram, an increase from $5.22 per kilogram in 2004. Mischmetal and specialty mischmetals composed most of the rare-earth metal imports. (Mischmetal is a natural mixture of rare-earth metals typically produced by metallothermic reduction of a mixed rare-earth chloride.) The price of basic mischmetal ranged from $2.88 to $3.75 per kilogram, and battery-grade mischmetal, from $4.26 to $5.01 per kilogram (metric ton quantities) in 2005, free on board (f.o.b.), China port (China Rare Earth Information,

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2005). The domestic price of mischmetal at $10.00 per kilogram (metric ton quantities) was higher than the Chinese price because of shipping costs related to its classification as a hazardous material since it is pyrophoric. The average price for imported cerium compounds, excluding cerium chloride, decreased to $3.27 per kilogram in 2005 from $4.67 per kilogram in 2004. The primary cerium compound imported was cerium carbonate.

The 2005 nominal price for bastnäsite concentrate was $5.51 per kilogram of contained lanthanide oxide ($2.50 per pound of contained lanthanide oxide). The price of monazite concentrate, typically sold with a minimum 55% rare-earth oxide (REO) content, including contained thorium oxide, f.o.b., as quoted in U.S. dollars and based on the last U.S. import data, was unchanged at $400.00 per metric ton ($0.73 per kilogram of contained rare-earth oxide). In 2005, no monazite was imported into the United States. Prices for monazite remained depressed because the principal international rare-earth processors continued to process only thorium-free feed materials.

The nominal price range for basic neodymium metal for metric ton quantities decreased slightly to $11.89 to $13.14 per kilogram, f.o.b. shipping point (China Rare Earth Information, 2005). Most NIB alloy was sold with additions of cobalt (typically 4% to 6%) or dysprosium (no more than 4%). The cost of the additions was based on pricing before shipping and alloying fees; with the average cobalt price increasing to $35.19 per kilogram in 2005, the cost would be about $0.35 per kilogram for each percentage point addition. The price of dysprosium metal was about $59.54 per kilogram, which would cost about $0.60 per kilogram for each percentage point addition.

Rhodia's quoted rare earth prices net 30 days, f.o.b. New Brunswick, NJ, or duty paid at point of entry, in effect at yearend 2005, are listed in table 3. No published prices for scandium oxide in kilogram quantities were available. Yearend 2005 nominal prices for scandium oxide were compiled from information provided by several domestic suppliers and processors. Prices for 2005 were essentially unchanged from those of 2004. The 2005 prices were as follows: 99% purity, $500 per kilogram; 99.9% purity, $1,300 per kilogram; 99.99% purity, $2,500 per kilogram; and 99.999% purity, $3,000 per kilogram.

Scandium metal prices for 2005 increased from those of 2004 and were as follows: 99.9% REO purity, metal pieces, distilled dendritic, ampouled under argon, $303 per 2 grams; 99.9% purity, metal ingot, $124 per gram; scandium rod, 12.7-millimeter (mm) diameter, 99.9% (metals basis excluding tantalum), $497 per 10 millimeters; and 99.9% REO purity foil, 0.025-mm thick, ampouled under argon, 25 x 25 mm, $141 per sheet (Alfa Aesar, undated §).

Scandium compound prices increased from 2004 and were as follows: scandium acetate hydrate 99.9% purity, $70.30 per gram; scandium chloride hydrate 99.99% purity, $92.80 per gram; scandium nitrate hydrate 99.9% purity, $111.50 per gram; and scandium sulfate pentahydrate 99.9% purity, $72.50 per gram. Prices for standard solutions for calibrating analytical equipment were $27.00 per 100 milliliters of scandium atomic absorption standard solution (Aldrich Chemical Co., 2005, p. 2083-2084).

Prices for kilogram quantities of scandium metal in ingot form have historically averaged about twice the cost of scandium oxide, and higher purity distilled scandium metal prices have averaged about five times that cost.

Foreign Trade

U.S. exports and imports decreased in quantity in 2005 compared with those of 2004. Data in this section are based on gross weight, while data in the tables may be converted to equivalent REO content, as specified. U.S. exports totaled 9,680 metric tons (t) valued at $50.9 million, a 20% decrease in quantity and a 6.6% decrease in value compared with those of 2004 (table 4). Imports totaled 22,300 t gross weight valued at $101 million, a 5.0% decease in quantity but a 2.9% increase in value compared with those of 2004 (table 5).

In 2005, U.S. exports of rare earths decreased in quantity in three out of four trade categories. Principal destinations in 2005, in descending order, were Germany, Canada, Estonia, and Japan. The United States exported 530 t of rare-earth metals valued at $5.18 million, a 37% decrease in quantity and a 14.3% decrease in value compared with that of 2004. Principal destinations of the rare-earth metals, in descending order by quantity, were Japan, China, Indonesia, and Germany. Exports of cerium compounds, primarily for glass polishing and automotive catalytic converters, decreased by 2.7% to 2,220 t valued at $13.6 million. Major destinations, in descending order of quantity, were India, Egypt, the Republic of Korea, and Japan.

Exports of inorganic and organic rare-earth compounds decreased by 56.9% to 2,070 t in 2005 from 4,800 t in 2004, and the value of the shipments decreased by 25.4% to $14.1 million. Shipments, in descending order of quantity, were to Estonia, China, Canada, and the United Kingdom.

U.S. exports of ferrocerium and other pyrophoric alloys increased to 4,860 t valued at $18.0 million in 2005 from 4,190 t valued at $16.8 million in 2004. Principal destinations, in descending order of quantity, were Germany, Canada, the Netherlands, Saudi Arabia, the United Kingdom, and the United Arab Emirates.

In 2005, U.S. imports of compounds and alloys decreased in quantity for two out of the seven categories and are listed in table 5. China dominated the import market, especially for mixed and individual rare-earth compounds, followed by France, Japan, Russia, and Estonia (fig. 1). These five countries accounted for 95.3% of the domestic imports.

Imports of cerium compounds totaled 3,249 t valued at $10.6 million. The quantity of cerium compounds imported increased by 15.4% as a result of increased demand for automotive exhaust catalysts and the value declined by 19.3%. China was the major supplier for the 11th consecutive year, followed by Japan, France, and Hong Kong.

Imports of yttrium compounds that contained between 19 and 85 weight-percent yttrium (yttrium concentrate) increased by 64.5% to 372 t in 2005, but the value decreased by 0.84% to $3.48 million. China was the leading supplier of yttrium compounds, followed by Japan and France.

Imports of individual rare-earth compounds, traditionally the major share of rare-earth imports, decreased by 24.8% compared with those of 2004. Rare-earth compound imports decreased to 11,400 t valued at $59.6 million. The major sources of individual rare-earth compounds, in decreasing order by quantity, were China, Japan, France, Russia, and the United Kingdom.

Imports of mixtures of rare-earth oxides, other than cerium oxide, decreased in quantity by 61.5% to 640 t valued at $6.3

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million. The principal source of the mixed rare-earth oxides was China, with much smaller quantities imported from Italy, the United Kingdom, Austria, and Japan.

Imports of rare-earth metals and alloys into the United States totaled 733 t valued at $4.90 million in 2005, a 9.4% increase in quantity compared with 2004. The principal rare-earth metal source was China, with much smaller amounts from Japan and Austria.

In 2005, imports of rare-earth chlorides increased by 104% to 5,810 t valued at $13.8 million. Supplies of rare-earth chloride, in descending order by quantity, came from China, with minor amounts from Japan, the United Kingdom, and Belgium. In the United States, rare-earth chloride was used mainly as feed material for manufacturing fluid cracking catalysts.

Imports of ferrocerium and pyrophoric alloys increased to 147 t valued at $2.05 million from 118 t valued at $1.77 million in 2004. Principal sources of these alloys, in descending order by quantity, were France, Austria, and China.

World Review

Australia.—Lynas Corporation Ltd. announced that it had completed its feasibility study on its Mount Weld rare-earth deposit in Western Australia (Lynas Corporation Ltd., 2005b). A pilot plant was completed and achieved a 63% recovery of REO from the ore, producing a 40% REO concentrate. Lynas planned to truck the concentrate from Mount Weld, near Laverton, to the port of Esperance. The concentrate is anticipated to be shipped from Esperance, Western Australia, to Shandong Province, China, for processing. The mining plan for Mount Weld is to recover 121,000 metric tons per year (t/yr) of ore, grading 14.8% REO, by open pit methods followed by flotation processing to produce 31,500 t/yr of a 40% REO concentrate. The concentrate is designed to be acid leached to produce several intermediate rare-earth products, including a cerium chloride, lanthanum-praseodymium-neodymium chloride, samarium-europium-gadolinium mixed oxide, and a mixed heavy rare-earth oxide containing terbium and dysprosium (Lynas Corporation Ltd., 2005b). Reserves at Mount Weld are 6.2 Mt grading 12.4% REO for a total content of 769,000 t of REO. Inferred resources are an additional 1.5 Mt grading 9.9% REO (Lynas Corporation Ltd., 2005a).

In addition to the rare-earth deposit, a separate group of rare-metal ore bodies in the north and northeast region of the Mount Weld carbonatite contain additional mineral resources. The rare-metal sectors contain resources of 1.5 Mt of titanium oxide, 470,000 t of REO, 400,000 t of niobium oxide, 110,000 t of zirconium oxide, and 9,070 t of tantalum oxide. The Mount Weld rare-metals deposit would be ranked as the second largest niobium deposit in the world behind the niobium deposit at Araxa, Brazil (Lynas Corporation Ltd., 2005a).

Lynas, which had announced the purchase of 19.92% of AMR Technologies Inc. in 2004, dropped its takeover strategy in 2005 and sold its holdings (Lynas Corporation Ltd., 2005a). AMR is a Canadian company based in Toronto, Ontario, that operated two rare-earth plants in China and a rare-earth bonded magnetic powder plant in Thailand.

Australia remained one of the world's major potential sources of rare-earth elements from its alkaline intrusive deposit, heavy-mineral sands deposits, and rare-earth lateritic deposits. Monazite is a constituent in essentially all of Australia's heavy-mineral sands deposits. It is normally recovered and separated during processing but, in most cases, is either returned to tailings because of a lack of demand or stored for future sale.

Alkane Exploration Ltd. announced that measured resources at its Dubbo zirconia project in New South Wales were 35.7 Mt of ore grading 1.96% zirconia, 0.75% REO (excluding yttria), 0.46% columbium (niobium) pentoxide, 0.14% yttria, 0.04% hafnia, and 0.03% tantalum trioxide. Inferred resources were an additional 37.5 Mt. Planned capacity of the Dubbo operation was 200,000 t/yr of ore, producing 3,000 t/yr of zirconia equivalent, 600 t/yr of columbium (niobium) and tantalum concentrate, and 1,200 t/yr of REO (yttria and lanthanide oxides). A decision on development of the Dubbo zirconia project was expected by 2006 (Alkane Exploration Ltd., 2005§).

Brazil.—Reserves of rare earths were 44,000 t contained in various types of deposits, including alkaline intrusives, carbonatites, fluvial or stream placers, lateritic ores, and marine placers. The reserves, comprising measured and indicated quantities of monazite, were distributed in deposits primarily in the States of Minas Gerais (11,730 t), Bahia (5,949 t), Espirito Santo (2,527 t), and Rio de Janeiro (2,454 t) (Anuario Mineral Brasil, 2006). Brazil produced 731 t of monazite in 2004, the latest date for which Government data were available (Fabricio da Silva, 2006).

China.—Production of rare-earth concentrates in China was a record high 118,709 t of REOs in 2005, an increase from the 98,310 t in 2004 (table 6). China consumed 51,900 t of equivalent REO in a variety of applications.

Production of rare-earth magnets reached 35,200 t of which 33,000 t was sintered NIBs, 1,800 t bonded NIBs, and 400 t samarium-cobalt magnets (China Rare Earth Information, 2006a).

China produced 6,000 t of cerium polishing compounds in 2005, an increase from the 5,500 t produced in 2004. The principal applications were in polishing cathode ray tubes (CRTs) and liquid crystal displays (LCDs). Lesser amounts were used in artware and glass, optical components, and miscellaneous applications.

Rare-earth phosphor consumption in color CRTs for television and computer monitors was 1,650 t; long afterglow phosphor materials, 1,500 t; and trichromatic fluorescent lamps, 2,500 t (China Rare Earth Information, 2006b). About 5,500 t of rare-earth catalysts was used in fluid cracking catalysts by the Chinese oil industry. In China, automotive catalytic converters consumed 2,050 t of rare earths for use in 8.4 million units.

China produced 13,000 t of rare-earth hydrogen storage alloys for NiMH batteries and used 4,333 t of REO. The NiMH alloy was used in the production of 8 billion to 9 billion units (China Rare Earth Information, 2006b).

Japan.—Rare earths were produced from imported ores and intermediate raw materials. Imports of refined rare-earth products were 31,106 t, an increase from the revised 26,758 t imported in 2004. The value of imports increased to ¥24.422 billion in 2005 from a revised ¥20.774 billion in 2004. Japanese imports of refined rare-earth products increased for cerium oxide, cerium compounds, rare-earth metals, and ferrocerium and decreased for all other categories.

Production of Japanese rare-earth-bonded magnets in 2005 was estimated to be 530 t, a decrease from the 600 t in 2004

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(Roskill's Letter from Japan, 2006b). Lower production of rare-earth-bonded magnets in 2005 was reportedly the result of an overall size reduction of spindle motors used in computer hard disk drives. Japanese production of NIB magnets in 2004, the latest available data, was 6,700 t, an increase from the 6,200 t produced in 2003. Magnet production consumed an estimated 4,200 t of neodymium metal and 420 t of dysprosium metal (Roskill's Letter from Japan, 2006d). China, however, was the world's principal producer of NIB magnets in 2005 with 27,510 t (Roskill's Letter from Japan, 2006c)

Japan also produced an estimated 8,500 t of rare-earth-sintered magnets in 2005, an increase from the 7,900 t produced in 2004 (Roskill's Letter from Japan, 2006d).

Japanese imports of rare earths from China were as follows: rare-earth metals, 8,385 t; cerium compounds (other than oxide), 5,317 t; cerium oxide, 5,206 t; rare-earth compounds, 5,140 t; lanthanum oxide, 1,758 t; yttrium oxide, 1,211 t; and ferrocerium, 262 t (Roskill's Letter from Japan, 2006d). China continued to be the leading source of rare-earth imports for Japan with 27,279 t in 2005, an increase from the revised 24,169 t imported in 2004.

Japanese imports of rare-earth refined products in 2005 were 31,106 t classified as follows: rare-earth metals, 8,387 t; cerium compounds (other than cerium oxide), 7,216 t; cerium oxide, 6,147 t; rare-earth compounds, 5,738 t; lanthanum oxide, 1,801 t; yttrium oxide, 1,226 t; and ferrocerium, 592 t (Roskill's Letter from Japan, 2006d).

Japan, the leading producer of rechargeable batteries in the world, produced 321 million units of rare-earth-containing NiMH batteries in 2005, a slight increase from the 319 million units produced in 2004 (Roskill's Letter from Japan, 2006a).

Current Research and Technology

Electron Energy Corporation announced that it had produced a short video featuring production of ultra-high-temperature samarium-cobalt magnets. The rare-earth permanent magnet is stable to 550° C and can operate continuously. Samarium-cobalt magnets are used in aerospace, electronics, instrumentation, medical, military, and motion control applications (Electron Energy Corporation, 2005§).

Outlook

Rare-earth use in automotive pollution control catalysts, permanent magnets, and rechargeable batteries are expected to continue to increase as future demand for conventional and hybrid automobiles, computers, electronics, and portable equipment grows. Rare-earth markets are expected to require greater amounts of higher purity mixed and separated products to meet the demand. Strong demand for cerium and neodymium for use in automotive catalytic converters and permanent magnets is expected to continue through 2010. Future growth is expected for rare earths in rechargeable NiMH batteries, especially those used in hybrid vehicles. NiMH demand is expected to increase (moderated by demand for lithium ion batteries) for use in portable equipment such as cell phones, laptop computers, portable DVD, CD, and MP3 players, and digital cameras and camcorders. Increased rare-earth use is expected in fiber optics, medical applications that include dental and surgical lasers, magnetic resonance imaging, medical contrast agents, medical isotopes, and positron emission tomography scintillation detectors. Future growth potential is projected for rare-earth alloys employed in magnetic refrigeration.

World reserves are sufficient to meet forecast world demand well into the 21st century. Several very large rare-earth deposits in Australia and China (for example Mianning in China and Mount Weld in Australia) have yet to be fully developed because world demand is currently being satisfied by existing production. Additionally, the Mountain Pass deposit in the United States contains sufficient resources to meet domestic demand if the foreign supply is compromised.

Domestic companies have shifted away from using naturally occurring radioactive rare-earth ores. This trend has resulted in ceased production and a loss of revenues for monazite-containing mineral sands operations worldwide. Long-term demand for monazite, however, is expected to increase because of its abundant supply and its recovery as a low-cost byproduct. Thorium's use as a nonproliferative nuclear fuel is considered a likely replacement for uranium in the future, especially in a world concerned with the threat of terrorism. As consumption of thorium increases, monazite could resume its role as a major source of rare earths. The cost and space requirements to dispose of radioactive waste products in the United States are expected to continue to increase, severely limiting domestic use of low-cost monazite and other thorium-bearing rare-earth ores.

Rare-earth producers outside of China, producing less than 5% of the world's supply, are expected to continue to struggle in competition with China's lower wages, inexpensive utilities, and fewer environmental and permitting requirements. China is expected to remain the world's principal rare-earth supplier. Economic growth in several developing countries will provide new and potentially large markets in India, Southeast Asia, and Eastern Europe.

The long-term outlook is for an increasingly competitive and diverse group of rare-earth suppliers. As research and technology continue to advance the knowledge of rare earths and their interactions with other elements, the economic base of the rare-earth industry is expected to continue to grow. New applications are expected to continue to be discovered and developed, especially in areas that are considered essential, such as energy and defense.

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TABLE 1
SALIENT U.S. RARE EARTH STATISTICS[1]

		2001	2002	2003	2004	2005
Production of rare-earth concentrates, rare-earth oxide (REO) basis[e, 2]	metric tons	W	W	--	--	--
Exports, REO basis:						
Cerium compounds	do.	4,120	2,740	1,910	2,280	2,220
Rare-earth metals, scandium, yttrium	do.	884	1,300	730	1,010	636
Rare-earth compounds, organic or inorganic	do.	1,600	1,340	1,790	4,800	2,070
Ferrocerium and pyrophoric alloys	do.	2,500	2,830	2,880	3,720	4,320
Imports for consumption, REO basis:[e]						
Cerium compounds	do.	3,850	2,540	2,430	1,880	2,170
Ferrocerium and pyrophoric alloys	do.	118	89	102	105	130
Metals, alloys, oxides, other compounds	do.	15,300	11,600	14,100	15,300	13,000
Prices, yearend:						
Bastnäsite concentrate, REO basis[e]	dollars per kilogram	$5.51	$5.51	$5.51	$5.51	$5.51
Monazite concentrate, REO basis[e]	do.	$0.73	$0.73	$0.73	$0.73	$0.73
Mischmetal, metal basis	do.	$16.00 [3]	$16.00 [3]	$10.00 [4]	$10.00 [4]	$10.00 [4]

[e]Estimated. W Withheld to avoid disclosing company prorietary data. -- Zero.
[1]Data are rounded to no more than three significant digits.
[2]Includes only the rare earths derived from bastnäsite as obtained from Molycorp, Inc.
[3]Source: Elements, TradeTech, Denver, CO.
[4]Source: Hefa Rare Earths Canada Co. Ltd., Vancouver, British Columbia, Canada.

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TABLE 2

RARE EARTH CONTENTS OF MAJOR AND POTENTIAL SOURCE MINERALS[1]

(Percentage of total rare-earth oxide)

	Bastnäsite		Monazite			
Rare earth	Mountain Pass, CA, United States[2]	Bayan Obo, Inner Mongolia, China[3]	North Capel, Western Australia[4]	North Stradbroke Island, Queensland, Australia[5]	Green Cove Springs, FL, United States[6]	Nangang, Guangdong, China[7]
Cerium	49.10	50.00	46.00	45.80	43.70	42.70
Dysprosium	trace	0.1	0.7	0.60	0.9	0.8
Erbium	trace	trace	0.2	0.2	trace	0.3
Europium	0.1	0.2	0.053	0.8	0.16	0.1
Gadolinium	0.2	0.7	1.49	1.80	6.60	2.00
Holmium	trace	trace	0.053	0.1	0.11	0.12
Lanthanum	33.20	23.00	23.90	21.50	17.50	23.00
Lutetium	trace	trace	trace	0.01	trace	0.14
Neodymium	12.00	18.50	17.40	18.60	17.50	17.00
Praseodymium	4.34	6.20	5.00	5.30	5.00	4.10
Samarium	0.8	0.8	2.53	3.10	4.90	3.00
Terbium	trace	0.1	0.035	0.3	0.26	0.7
Thulium	trace	trace	trace	trace	trace	trace
Ytterbium	trace	trace	0.1	0.1	0.21	2.40
Yttrium	0.10	trace	2.40	2.50	3.20	2.40
Total	100	100	100	100	100	100

	Monazite—Continued		Xenotime		Rare earth laterite	
	Eastern coast, Brazil[8]	Mount Weld, Australia[9]	Lahat, Perak, Malaysia[2]	Southeast Guangdong, China[10]	Xunwu, Jiangxi Province, China[11]	Longnan, Jiangxi Province, China[11]
Cerium	47.00	51.00	3.13	3.00	2.40	0.4
Dysprosium	0.4	0.2	8.30	9.10	trace	6.70
Erbium	0.1	0.2	6.40	5.60	trace	4.90
Europium	0.1	0.4	trace	0.2	0.5	0.10
Gadolinium	1.00	1.00	3.50	5.00	3.00	6.90
Holmium	trace	0.1	2.00	2.60	trace	1.60
Lanthanum	24.00	26.00	1.24	1.20	43.4	1.82
Lutetium	not determined	trace	1.00	1.80	0.1	0.4
Neodymium	18.50	15.00	1.60	3.50	31.70	3.00
Praseodymium	4.50	4.00	0.5	0.6	9.00	0.7
Samarium	3.00	1.80	1.10	2.20	3.90	2.80
Terbium	0.1	0.1	0.9	1.20	trace	1.30
Thulium	trace	trace	1.10	1.30	trace	0.7
Ytterbium	0.02	0.1	6.80	6.00	0.3	2.50
Yttrium	1.40	trace	61.00	59.30	8.00	65.00
Total	100	100	100	100	100	100

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 3
RARE-EARTH OXIDE PRICES IN 2005

Product (oxide)	Purity (percentage)	Standard package quantity (kilograms)	Price (dollars per kilogram)
Cerium	96.00	25	19.20
Do.	99.50	900	31.50
Dysprosium	99.00	3	120.00
Erbium	96.00	2	155.00
Europium	99.99	1	990.00 [1]
Gadolinium	99.99	3	130.00
Holmium	99.90	10	440.00 [2]
Lanthanum	99.99	25	23.00
Lutetium	99.99	2	3,500.00
Neodymium	95.00	20	28.50
Praseodymium	96.00	20	36.80
Samarium	99.90	25	360.00
Do.	99.99	25	435.00
Scandium	99.99	1	6,000.00
Terbium	99.99	5	535.00
Thulium	99.90	5	2,300.00
Ytterbium	99.00	10	340.00
Yttrium	99.99	50	88.00

[1]Price for quantity greater than 40 kilograms is $900.00 per kilogram.
[2]Price for quantity less than 10 kilograms is $485.00 per kilogram.

Source: Rhodia Electronics & Catalysis, Inc.

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TABLE 4

U.S. EXPORTS OF RARE EARTHS, BY COUNTRY[1]

Category[2] and country	2004		2005	
	Gross weight (kilograms)	Value	Gross weight (kilograms)	Value
Cerium compounds (2846.10.0000):				
Australia	5,830	$7,090	--	--
Austria	130,000	746,000	104,000	$633,000
Belgium	3,000	27,900	2,400	23,600
Brazil	55,700	311,000	123,000	661,000
Canada	47,800	270,000	22,900	263,000
China	25,800	254,000	78,600	582,000
Egypt	468,000	2,420,000	378,000	1,700,000
France	8,390	74,500	41,700	248,000
Germany	168,000	832,000	98,700	494,000
Hong Kong	91,200	782,000	92,100	793,000
India	295,000	1,760,000	508,000	2,690,000
Japan	180,000	1,350,000	165,000	1,410,000
Korea, Republic of	342,000	1,130,000	197,000	594,000
Malaysia	80,200	252,000	55,800	199,000
Mexico	203,000	1,080,000	141,000	964,000
Netherlands	16,000	142,000	13,900	164,000
Singapore	10,600	63,300	4,290	26,900
Taiwan	7,110	72,500	17,800	141,000
United Kingdom	38,700	375,000	54,100	582,000
Other	99,200 r	695,000 r	116,000	1,390,000
Total	2,280,000	12,600,000	2,220,000	13,600,000
Total estimated equivalent rare-earth oxide (REO) content	2,280,000	12,600,000	2,220,000	13,600,000
Rare-earth compounds[3] (2846.90.0000):				
Argentina	--	--	17,600	117,000
Austria	17,000	454,000	--	--
Brazil	5,330	146,000	51,100	363,000
Canada	1,960,000	3,860,000	266,000	719,000
China	23,100	155,000	273,000	1,170,000
Colombia	2,840	18,400	3,730	56,100
Estonia	1,800,000	1,030,000	846,000	406,000
France	38,100	1,100,000	47,900	1,190,000
Germany	255,000	775,000	20,400	497,000
Guatemala	--	--	63,900	30,900
Hong Kong	29,000	661,000	28,900	818,000
India	3,520	17,200	6,160	37,000
Italy	29,900	600,000	2,720	24,500
Japan	80,200	3,850,000	28,400	5,740,000
Korea, Republic of	145,000	1,150,000	63,200	508,000
Mexico	23,800	160,000	20,400	146,000
Netherlands	12,400	830,000	570	22,900
Poland	34,600	1,230,000	21,300	439,000
Russia	45,800	35,200	--	--
Singapore	5,290	165,000	523	71,600
Taiwan	83,900	1,660,000	30,400	712,000
United Kingdom	29,800	482,000	184,000	643,000
Other	184,000	530,000	92,900	389,000
Total	4,800,000	18,900,000	2,070,000	14,100,000
Total estimated equivalent REO content	4,800,000	18,900,000	2,070,000	14,100,000

See footnotes at end of table.

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TABLE 4—Continued

U.S. EXPORTS OF RARE EARTHS, BY COUNTRY[1]

Category[2] and country	2004 Gross weight (kilograms)	2004 Value	2004 Gross weight (kilograms)	2004 Value
Rare-earth metals, including scandium and yttrium (2805.30.0000):				
Belgium	739	$28,800	750	$29,300
Brazil	8,410	188,000	300	10,800
China	105,000	1,610,000	24,700	340,000
Germany	4,040	214,000	5,970	326,000
Hong Kong	10	5,610	660	17,300
India	489	23,000	1,790	87,300
Indonesia	159,000	218,000	17,200	26,700
Japan	559,000	3,380,000	475,000	3,910,000
Mexico	699	58,500	1,660	70,100
Switzerland	226	31,300	305	69,600
Taiwan	1,460	58,600	955	67,600
Other	1,470 r	229,000 r	485	224,000
Total	840,000	6,050,000	530,000	5,180,000
Total estimated equivalent REO content	1,010,000	6,050,000	636,000	5,180,000
Ferrocerium and other pyrophoric alloys (3606.90.0000):				
Argentina	1,130	$10,700	24,600	$37,700
Australia	51,300	1,810,000	19,600	2,630,000
Bahrain	36,800	34,200	36,600	38,300
Canada	654,000	2,560,000	762,000	1,950,000
Cyprus	39,800	62,400	18,300	21,100
Egypt	115,000	106,000	105,000	104,000
France	56,900	181,000	115,000	474,000
Germany	1,110,000	5,780,000	1,510,000	2,080,000
Greece	57,100	65,400	62,000	113,000
Hong Kong	166,000	346,000	144,000	624,000
Israel	102,000	149,000	68,000	73,300
Japan	151,000	2,760,000	135,000	4,830,000
Jordan	50,600	41,600	60,800	60,100
Korea, Republic of	1,090	69,300	35,200	605,000
Kuwait	97,000	77,500	166,000	150,000
Mexico	32,400	136,000	23,900	146,000
Morocco	11,000	9,380	24,600	23,500
Netherlands	437,000	908,000	585,000	1,870,000
New Zealand	12,300	21,400	24,700	40,700
Portugal	19,100	34,900	21,500	42,500
Russia	25,000	33,000	46,200	73,300
Saudi Arabia	83,900	128,000	306,000	518,000
Singapore	13,600	69,000	7,560	90,000
Taiwan	6,820	44,600	8,840	60,600
Thailand	--	--	22,900	116,000
United Arab Emirates	259,000	237,000	195,000	223,000
United Kingdom	268,000	457,000	301,000	613,000
Other	326,000 r	708,000 r	32,000	422,000
Total	4,190,000	16,800,000	4,860,000	18,000,000
Total estimated equivalent REO content	3,720,000	16,800,000	4,320,000	18,000,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States category numbers.

[3]Inorganic and organic.

Source: U.S. Census Bureau.

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TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY[1]

Category[2] and country	2004 Gross weight (kilograms)	2004 Value	2005 Gross weight (kilograms)	2005 Value
Cerium compounds, including oxides, hydroxides, nitrates, sulfate chlorides, oxalates (2846.10.0000):				
Austria	39,000	$371,000	18,300	$188,000
China	2,260,000	4,450,000	2,840,000	4,890,000
France	190,000	2,500,000	83,700	1,000,000
Hong Kong	--	--	36,000	77,500
Ireland	13,900	350,000	13,900	350,000
Japan	270,000	5,050,000	211,000	3,850,000
Korea, Republic of	41,400	369,000	25,900	59,500
Netherlands	8	4,660	449	13,400
United Kingdom	386	13,000	17,200	175,000
Other	931 r	40,100 r	1,220	11,100
Total	2,820,000	13,200,000	3,250,000	10,600,000
Total estimated equivalent rare-earth oxide (REO) content	1,880,000	13,200,000 r	2,170,000	10,600,000
Yttrium compounds content by weight greater than 19% but less than 85% oxide equivalent (2846.90.4000):				
China	211,000	1,350,000	360,000	1,630,000
France	3,470	204,000	535	33,800
Japan	10,900	1,950,000	11,600	1,800,000
Other	462	16,700	140	26,000
Total	226,000	3,510,000	372,000	3,480,000
Total estimated equivalent REO content	136,000	3,510,000	223,000	3,480,000
Rare-earth compounds, including oxides, hydroxides, nitrates, other compounds except chlorides (2846.90.8000):				
Austria	91,300	3,230,000	126,000	5,460,000
Canada	17	34,300	18,000	58,200
China	11,100,000	29,400,000	9,430,000	25,500,000
Estonia	440,000	428,000	76,000	80,000
France	1,990,000	13,600,000	518,000	9,290,000
Germany	23,600	714,000	8,000	521,000
Hong Kong	24,600	382,000	400	104,000
Japan	789,000	9,640,000	695,000	12,200,000
Russia	672,000	1,220,000	377,000	680,000
South Africa	--	--	10,600	63,600
United Kingdom	45,800	5,090,000	147,000	5,540,000
Other	25,200	315,000 r	366	92,300
Total	15,200,000	64,100,000	11,400,000	59,600,000
Total estimated equivalent REO content	11,400,000	64,100,000	8,550,000	59,600,000
Mixtures of REOs except cerium oxide (2846.90.2010):				
Austria	6,300	307,000	7,760	157,000
China	1,630,000	3,860,000	578,000	1,960,000
Germany	--	--	3,380	44,900
Ireland	--	--	1,270	141,000
Italy	--	--	34,500	3,720,000
Japan	9,540	524,000	3,540	140,000
Russia	143	91,000	51	10,800
United Kingdom	12,900	84,300	10,100	43,600
Other	248	67,100	1,780	103,000
Total	1,660,000	4,930,000	640,000	6,320,000
Total estimated equivalent REO content	1,660,000	4,930,000	640,000	6,320,000

See footnotes at end of table.

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TABLE 5—Continued

U.S. IMPORTS FOR CONSUMPTION OF RARE EARTHS, BY COUNTRY[1]

Category[2] and country	2004 Gross weight (kilograms)	2004 Value	2005 Gross weight (kilograms)	2005 Value
Rare-earth metals, whether intermixed or alloyed (2805.30.0000):				
Austria	5,350	$115,000	28,500	$1,530,000
China	632,000	2,780,000	664,000	2,880,000
Germany	2,000	24,500	62	3,560
Italy	5,900	30,100	--	--
Japan	13,200	216,000	31,100	206,000
Russia	1,010	119,000	979	117,000
United Kingdom	10,400	177,000	7,660	164,000
Other	233	36,400	600	2,390
Total	670,000	3,500,000	733,000	4,900,000
Total estimated equivalent REO content	804,000	3,500,000	880,000	4,900,000
Mixtures of rare-earth chlorides, except cerium chloride (2846.90.2050):				
Belgium	13,000	122,000	10,000	26,200
China	2,750,000	2,670,000	5,760,000	6,420,000
France	10,900	83,400	--	--
Germany	247	158,000	138	92,700
Israel	1,000	879,000	--	--
Japan	24,500	483,000	22,700	6,990,000
Korea, Republic of	37,800	2,140,000	--	--
Mexico	--	--	960	28,800
Netherlands	15,000	83,100	--	--
Russia	1,140	222,000	54	98,700
United Kingdom	2,400	15,400	13,600	92,300
Other	12 r	6,570 r	19	17,800
Total	2,850,000	6,870,000	5,810,000	13,800,000
Total estimated equivalent REO content	1,310,000	6,870,000	2,670,000	6,330,000
Ferrocerium and other pyrophoric alloys (3606.90.3000):				
Austria	18,800	402,000	14,300	289,000
Belgium	2,300	39,200	--	--
China	--	--	12,300	86,100
France	97,100	1,330,000	119,000	1,640,000
Japan	211	5,430	--	--
South Africa	--	--	522	23,100
Other	--	--	392	7,520
Total	118,000	1,770,000	147,000	2,050,000
Total estimated equivalent REO content	105,000	1,770,000	130,000	2,050,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States category numbers.

Source: U.S. Census Bureau.

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TABLE 6
RARE EARTHS: ESTIMATED WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons of rare earth oxide equivalent)

Country[3]	2001	2002	2003	2004	2005
Brazil	--	--	--	402 [4]	440
China	80,600	88,000	92,000	98,000	119,000
Commonwealth of Independent States[5]	NA	NA	NA	NA	NA
India	2,700	2,700	2,700	2,700	2,700
Kyrgyzstan:					
Compounds	NA	NA	NA	NA	NA
Metals	3,800	100	NA	NA	NA
Other	2,000	2,000	2,000	NA	NA
Malaysia	351 [4]	240	360	800 [r]	750
United States[6]	W	W	--	--	--
Total	89,500	93,000	97,000	102,000 [r]	123,000

[r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.
[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]Table includes data available through June 13, 2006.
[3]In addition to the countries listed, rare-earth minerals are believed to be produced in some Commonwealth of Independent States countries besides Kyrgyzstan and in Indonesia, Nigeria, North Korea, and Vietnam, but information is inadequate for formulation of reliable estimates of output levels.
[4]Reported figure.
[5]Does not include Kyrgyzstan; information is inadequate for formulation of reliable estimates for individual producing countries, including Kazakhstan, Russia, and Ukraine.
[6]Comprises only the rare earths derived from bastnäsite.

TABLE 7
MONAZITE CONCENTRATE: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, gross weight)

Country[3]	2001	2002	2003	2004	2005
Brazil	--	--	--	731 [4]	800 [p]
India	5,000	5,000	5,000	5,000	5,000
Malaysia	643 [4]	441 [4]	795 [4]	1,683 [r, 4]	700
Total	5,640	5,440	5,800	7,410 [r]	6,500

[p]Preliminary. [r]Revised. -- Zero.
[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.
[2]Table includes data available through April 18, 2006.
[3]In addition to the countries listed, China, Indonesia, Nigeria, North Korea, the Republic of Korea, and countries of the Commonwealth of Independent States may produce monazite; available general information is inadequate for formulation of reliable estimates of output levels.
[4]Reported figure.

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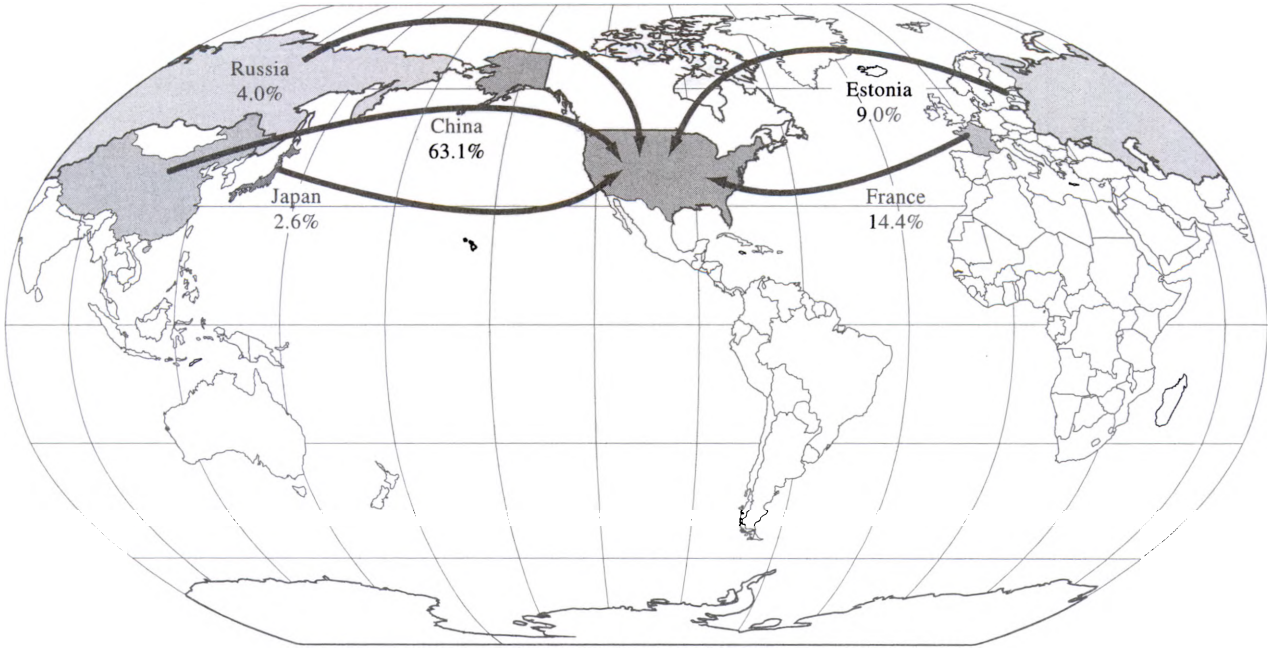
FIGURE 1
PRINCIPAL SOURCES OF U.S. IMPORTS OF RARE EARTHS, BY WEIGHT, IN 2005



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RECYCLING—METALS

By John F. Papp

Survey data and tables were prepared by Patricia A. Plunkert, Daniel L. Edelstein, Michael D. Fenton, Peter N. Gabby, Peter H. Kuck, James F. Carlin, Jr., Joseph Gambogi, Lisa A. Corathers, and Nicholas A. Muniz.

In 2005, the United States recycled 71 million metric tons (Mt) of metal, an amount equivalent to 52% of the apparent supply of those metals (table 1). The United States exported 17.7 Mt of scrap metal and imported 5.3 Mt (table 2).

Metals are important, reusable resources. Although the ultimate supply of metal is fixed by nature, human ingenuity determines the quantity of supply available for use by developing economic processes for the recovery from the Earth (the primary source of metal) and from secondary sources (recycled from the use/process stream). The reusable nature of metals contributes to the sustainability of their use.

Recycling, a significant factor in the supply of many of the metals used in our society, provides environmental benefits, such as energy savings, reduced volumes of waste, and reduced emissions associated with energy savings.

Individual annual reviews for each of the metals listed in the tables are in the respective chapters in this volume of the U.S. Geological Survey (USGS) Minerals Yearbook, volume I, Metals and Minerals.

The term "primary" indicates material from ore deposits, and the term "secondary" indicates material from recycled material, including used products and residual materials from manufacturing. Recycling practices and the description of those practices vary substantially among the metal industries. Generally, scrap is categorized as "new" or "old." "New" indicates preconsumer sources, and "old," postconsumer sources. The many stages of industrial processing that precede formation of an end product are the sources of new scrap. For example, when metal is converted into shapes—bars, plates, rods, or sheets—new scrap is generated in the form of cuttings, trimmings, and off-specification materials. When these shapes are converted to parts, new scrap may be generated in the form of cuttings, stampings, turnings, and off-specification materials. Similarly, when parts are assembled into products, new scrap is generated. Once a product completes its useful product life, it becomes old scrap. Used appliances, automobiles, and beverage cans are examples of old consumer scrap; used jet engine blades and vanes, junked machinery and ships, and metal recovered from commercial buildings or industrial plants are examples of old industrial scrap. A wide variety of descriptive terms, including external scrap, home scrap, internal scrap, mill scrap, prompt scrap, and purchased scrap, have evolved to describe scrap generated by diverse industry practices. The material flow of recycled metal commodities in the United States has been documented in a series of reports published by the USGS (Sibley, 2004).

Reference Cited

Sibley, S.F., ed., 2004, Flow studies for recycling metal commodities in the United States: U.S. Geological Survey Circular 1196-A–M, 210 p.

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TABLE 1
SALIENT U.S. RECYCLING STATISTICS FOR SELECTED METALS[1]

Year	Quantity of metal (metric tons)					Value of metal (thousands)			
	Recycled from new scrap[2]	Recycled from old scrap[3]	Recycled[4]	Apparent supply[5]	Percentage recycled	Recycled from new scrap[2]	Recycled from old scrap[3]	Recycled[4]	Apparent supply[6]
Aluminum:[7]									
2001	1,760,000	1,210,000	2,970,000	7,990,000	37	2,670,000	1,830,000	4,500,000	12,100,000
2002	1,750,000	1,170,000	2,930,000	8,070,000	36	2,510,000	1,680,000	4,190,000	11,500,000
2003	1,750,000	1,070,000	2,820,000	7,880,000	36	2,620,000	1,610,000	4,230,000	11,800,000
2004	1,870,000	1,160,000	3,030,000	8,460,000	36	3,640,000	2,140,000	5,600,000	15,700,000
2005	1,930,000	1,060,000	2,990,000	8,390,000	36	3,870,000	2,140,000	6,000,000	16,800,000
Chromium:[8]									
2001	NA	NA	141,000	532,000 r	27 r	NA	NA	81,900	223,000
2002	NA	NA	174,000	479,000	36	NA	NA	95,100	293,000
2003	NA	NA	180,000	532,000	34	NA	NA	139,000	429,000
2004	NA	NA	168,000	555,000	30	NA	NA	207,000	681,000
2005	NA	NA	124,000	511,000	24	NA	NA	162,000	717,000
Copper:[9]									
2001	833,000	317,000	1,150,000	3,340,000	34.4	1,410,000	536,000	1,950,000	5,660,000
2002	842,000	208,000	1,050,000	3,450,000	30.4	1,410,000	348,000	1,760,000	5,770,000
2003	738,000	206,000	944,000	3,170,000	29.8	1,390,000	387,000	1,770,000	5,950,000
2004	774,000	191,000	965,000	3,330,000	28.9	2,290,000	565,000	2,850,000	9,830,000
2005	769,000	182,000	951,000	3,170,000	30.0	2,940,000	698,000	3,640,000	12,100,000
Iron and steel:[10]									
2001	NA	NA	70,600,000	118,000,000	60	NA	NA	5,320,000	8,880,000
2002	NA	NA	69,300,000 r	119,000,000	58	NA	NA	6,450,000	10,200,000
2003[11]	NA	NA	65,500,000	117,000,000	56	NA	NA	7,920,000 r	13,200,000
2004[11]	NA	NA	66,900,000 r	132,000,000	51	NA	NA	14,100,000 r	24,900,000
2005	NA	NA	65,400,000	122,000,000	54	NA	NA	12,600,000	21,900,000
Lead:[12]									
2001	55,300	1,040,000	1,100,000	1,670,000	75.6	53,200	1,010,000	1,060,000	1,610,000
2002	42,600	1,070,000	1,120,000	1,540,000	81.2	40,900	1,030,000	1,070,000	1,480,000
2003r	19,300	1,120,000	1,140,000	1,520,000	77.4	18,600	1,080,000	1,100,000	1,470,000
2004	12,900	1,110,000 r	1,130,000 r	1,460,000 r	77.3 r	15,600	1,350,000 r	1,370,000 r	1,440,000 r
2005	15,700	1,130,000	1,140,000	1,540,000	74.5	21,100	1,520,000	1,540,000	2,070,000
Magnesium:[13]									
2001	38,600	27,200	65,800	151,000	44	106,000	75,000	181,000	416,000
2002	47,100	26,400	73,600	148,000	50	126,000	70,500	196,000	395,000
2003	44,700	25,400	70,100	152,000	46	107,000	60,900	168,000	366,000
2004	51,500 r	20,500 r	72,000 r	179,000 r	40	167,000	66,400	233,000 r	582,000 r
2005	53,400	19,400	72,800	167,000	44	172,000	62,500	234,000	538,000
Nickel:[14]									
2001	NA	NA	81,200	210,000	39	NA	NA	483,000	1,250,000
2002r	NA	NA	83,900	205,000	41	NA	NA	568,000	1,380,000
2003	NA	NA	83,500	200,000 r	42	NA	NA	804,000	1,930,000 r
2004	NA	NA	83,300	212,000 r	39	NA	NA	1,150,000	2,930,000 r
2005	NA	NA	77,300	214,000	36	NA	NA	1,140,000	3,150,000
Tin:[15]									
2001	7,210	6,700	13,900	46,300	30	24,400	29,900	54,300	316,000
2002	3,790	6,760	10,600	49,100	22	18,400	40,600	59,000	307,000
2003	3,570	5,500	9,070	41,500	22	26,800	41,200	68,000	311,000
2004	3,590	5,240 r	8,830 r	53,800 r	16	43,300 r	63,200 r	107,000 r	649,000 r
2005	2,280	11,800	14,000	46,500	30	24,300	125,000	150,000	495,000
Titanium:[16]									
2001	NA	NA	17,000	W	39	NA	NA	35,200 e	NA
2002	NA	NA	11,600	W	40	NA	NA	25,600 e	NA
2003	NA	NA	14,300	W	46	NA	NA	48,000 e	NA
2004	NA	NA	18,300 r	W	46 r	NA	NA	127,000 e	NA
2005	NA	NA	25,700	W	50	NA	NA	445,000	NA

See footnotes at end of table.

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TABLE 1—Continued
SALIENT U.S. RECYCLING STATISTICS FOR SELECTED METALS[1]

Year	Quantity of metal (metric tons)				Percentage recycled	Value of metal (thousands)			
	Recycled from new scrap[2]	Recycled from old scrap[3]	Recycled[4]	Apparent supply[5]		Recycled from new scrap[2]	Recycled from old scrap[3]	Recycled[4]	Apparent supply[6]
Zinc:[17]									
2001[r]	317,000	57,000	375,000	1,420,000	26.4	307,000	55,200	362,000	1,380,000
2002	319,000	47,300	366,000	1,420,000	25.8	272,000	40,300	312,000	1,210,000
2003	295,000	50,300	345,000	1,340,000	25.8	264,000	45,100	309,000	1,200,000
2004	302,000	47,100	349,000	1,400,000	24.9	350,000[r]	54,500[r]	404,000[r]	1,620,000[r]
2005	302,000	43,100	345,000	1,170,000	29.5	446,000	63,700	510,000	1,730,000

[e]Estimated. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Scrap that results from the manufacturing process, including metal and alloy production. New scrap of aluminum, copper, lead, tin, and zinc excludes home scrap, which is scrap generated and recycled in the metal producing plant.

[3]Scrap that results from consumer products.

[4]Metal recovered from new plus old scrap.

[5]Apparent supply is production plus net imports plus stock changes. Production is primary production plus recycled metal. Net imports are imports minus exports. Apparent supply is calculated on a contained-weight basis.

[6]Same as apparent supply defined in footnote 5 above but calculated based on a monetary value.

[7]Quantity of metal is the calculated metallic recovery from purchased new and old aluminum-base scrap, estimated for full industry coverage. Monetary value is estimated based on average U.S. market price for primary aluminum metal ingot.

[8]Chromium scrap includes estimated chromium content of stainless steel scrap receipts (reported by the iron and steel and pig iron industries) where chromium content was estimated to be 17%. Trade includes reported or estimated chromium content of chromite ore, ferrochromium, chromium metal and scrap, and a variety of chromium-containing chemicals. Stocks include estimated chromium content of reported and estimated producer, consumer, and Government stocks. Recycled value calculated from quantity using the average annual import value of high-carbon ferrochromium. Apparent supply value calculated from quantity using average annual trade value.

[9]Includes copper recovered from unalloyed and alloyed copper-base scrap, as refined copper or in alloy forms, as well as copper recovered from aluminum-, nickel-, and zinc-base scrap. Monetary value based on annual average refined copper prices.

[10]Iron production measured as shipments of iron and steel products plus castings corrected for imported ingots and blooms. Secondary production measured as reported consumption. Apparent supply includes production of raw steel.

[11]Before 2003, monetary value based on U.S. annual average composite price for No. 1 heavy-melting steel calculated from prices published in American Metal Market. After 2002, monetary value based on mass-weighted average of steel trade (exports plus imports) of selected Harmonized Tariff Schedule of the United States (HTS) categories. Recycled unit value based on HTS 7204 by year and per metric ton was 2003—$172 and 2004—$252. Steel production unit value based in HTS 7206 and 7207 by year and per metric ton was 2003—$259; 2004—$679. Apparent supply value is mass weighted-average of recycled production unit values.

[12]Lead processors are segregated by primary and secondary producers. This segregation permits inclusion of stock changes for secondary producers. Monetary value of scrap and apparent supply estimated based upon average quoted price of common lead.

[13]Includes magnesium content of aluminum-base scrap. Monetary value based on the annual average Platts Metals Week's U.S. spot Western price.

[14]Nickel statistics were derived from the following:

Canvass data
- •Reported nickel content of products made from reclaimed stainless steel dust, spent nickel-cadmium batteries, plating solutions, and other products.
- •Estimated nickel content of reported net receipts of alloy and stainless steel scrap.
- •Reported nickel content of recovered copper-base scrap.
- •Reported nickel content of obsolete and prompt purchased nickel-base scrap.
- •Estimated nickel content of various types of reported obsolete and prompt aluminum scrap.

Trade data
- •Reported nickel content of International Nickel Study Group (INSG) class I primary products, including briquets, cathode, flake, pellets, and powder.
- •Reported or estimated nickel content of INSG class II primary products, including ferronickel, metallurgical-grade nickel oxide, and a variety of nickel-containing chemicals.
- •Estimated nickel content of secondary products, including nickel waste and scrap and stainless steel scrap.

Stock data
- •Reported or estimated nickel content of all scrap stocks, except copper.
- •Reported nickel content of primary products held by world producers in U.S. warehouses.
- •Reported nickel content of primary products held by U.S. consumers.
- •Reported nickel content of U.S. Government stocks.

Monetary value based on annual average cash price for cathode, as reported by the London Metal Exchange.

[15]Monetary value based on Platts Metals Week composite price for tin.

[16]Percentage recycled based on titanium scrap consumed divided by primary sponge and scrap consumption.

[17]Monetary value based on annual average Platts Metal Week metal price for North American special high-grade zinc.

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TABLE 2
SALIENT U.S. RECYCLING TRADE STATISTICS FOR SELECTED METALS[1]

	Exports			Imports for consumption		
	Quantity			Quantity		
Year	Gross weight (metric tons)	Contained weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Contained weight (metric tons)	Value (thousands)
Aluminum:						
2001	580,000	NA	588,000	497,000	NA	552,000
2002	613,000	NA	603,000	466,000	NA	502,000
2003	577,000	NA	633,000	440,000	NA	496,000
2004	660,000	NA	773,000	535,000	NA	655,000
2005	1,090,000	NA	1,370,000	482,000	NA	658,000
Chromium:[2]						
2001	439,000	75,600	281,000	50,500	15,400	74,100
2002	343,000	59,000	259,000	88,500	21,200	92,200
2003	505,000	86,700	394,000	97,700	23,700	115,000
2004	479,000	82,200	565,000	156,000	34,500	216,000
2005	586,000	100,000	687,000	122,000	29,900	211,000
Copper:[3]						
2001	534,000	439,000	538,000	115,000	91,100	140,000
2002	511,000	407,000	509,000	100,000	80,300	124,000
2003	689,000	558,000	664,000	90,600	70,700	121,000
2004	714,000	578,000	882,000	102,000	79,800	183,000
2005	658,000	556,000	1,060,000	114,000	90,300	270,000
Iron and steel:						
2001	7,530,000	7,530,000	1,150,000	2,810,000	2,810,000	298,000
2002	9,000,000	9,000,000	1,300,000	3,320,000	3,320,000	403,000
2003	10,900,000	10,900,000	1,960,000	3,690,000	3,690,000	556,000
2004	11,800,000	11,800,000	2,930,000	4,790,000	4,790,000	1,280,000
2005	13,000,000	13,000,000	3,460,000	4,000,000	4,000,000	972,000
Lead:						
2001	108,000	108,000	24,900	10,700	10,000	4,260
2002	106,000	106,000	23,300	2,880	2,570	1,740
2003	92,800	92,800	23,300	4,970	4,600	2,460
2004	56,300	56,300	14,800	5,320	4,770	3,510
2005	67,300	67,300	21,600	3,840	3,340	2,880
Magnesium:						
2001	6,950	6,950	18,600	11,000	11,000	19,200
2002	5,850	5,850	14,700	14,100	14,100	20,900
2003	5,040	5,040	11,800	16,200	16,200	22,000
2004	4,790	4,790	11,300	11,700	11,700	17,600
2005	5,630	5,630	13,100	14,700	14,700	22,700
Nickel:[4]						
2001	1,070,000	51,000	533,000	252,000	9,550	95,000
2002	1,070,000	42,200	506,000	358,000	10,200	107,000
2003	1,410,000	50,900	704,000	230,000	12,000	138,000
2004	2,240,000	55,200	995,000	453,000	20,000	328,000
2005	2,170,000	61,900	1,190,000	550,000	17,200	304,000
Tin:						
2001	3,230	3,230	4,640	3,700	3,700	1,860
2002	5,940	5,940	9,740	561	561	736
2003	5,040	5,040	8,630	921	921	686
2004	9,310	9,310	13,200	1,950	1,950	1,700
2005	10,600	10,600	12,100	3,530	3,530	2,010
Titanium:						
2001	7,500	7,500	18,300	11,600	11,600	41,200
2002	6,000	6,000	14,200	6,270	6,270	17,800
2003	5,320	5,320	29,200	5,550	5,550	19,700
2004	9,760	9,760	56,000	8,830	8,830	53,600
2005	20,600	20,600	91,400	12,400	12,400	162,000

See footnotes at end of table.

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TABLE 2—Continued
SALIENT U.S. RECYCLING TRADE STATISTICS FOR SELECTED METALS[1]

	Exports			Imports for consumption		
	Quantity			Quantity		
Year	Gross weight (metric tons)	Contained weight (metric tons)	Value (thousands)	Gross weight (metric tons)	Contained weight (metric tons)	Value (thousands)
Zinc:						
2001	26,800	NA	14,200	39,300	NA	11,600
2002	19,800	NA	11,200	31,200	NA	9,530
2003	32,300	NA	23,300	10,300	NA	5,740
2004	40,300	NA	39,400	10,800	NA	7,740
2005	46,800	NA	55,000	9,580	NA	8,820

[r]Revised. NA Not available.

[1]Contained weight based upon 100% of gross, unless otherwise specified.

[2]Contained weight for import and export quantities of Harmonized Tariff Schedule of the United States (HTS) code 7204.21.000 is 17% of gross weight.

[3]For HTS codes 7404.00.0045, 7404.00.0062, 7404.00.0080 contained weight for import quantity is 65% of gross weight. For HTS codes 7404.00.3045, 7404.00.3055, 7404.00.3065, 7404.00.3090, 7404.00.6045, 7404.00.6055, 7404.00.65, and 7404.00.6090 contained weight for import quantity is 72%.

[4]Contained weight for import and export quantities is 0.4% of gross weight for HTS code 7204.29.000, 50% for HTS code 7503.00.00, and 7.5% for HTS code 7204.21.0000.

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RHENIUM

By Michael J. Magyar

Domestic survey data and tables were prepared by Jo-Ann S. Sterling, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

In the past decade, the two most important uses of rhenium have been in high-temperature superalloys and platinum-rhenium catalysts. High-temperature superalloys are used in single-crystal turbine blades in aircraft engines and other land-based turbine applications. Platinum-rhenium catalysts are used to produce high-octane, lead-free gasoline. Other applications of rhenium, primarily as tungsten-rhenium and molybdenum-rhenium alloys, are more diverse; these included electrical contact points, flashbulbs, heating elements, metallic coatings, temperature controls, thermocouples, vacuum tubes, and x-ray tubes and targets. Industry continued research on rhenium recovery from recycling turbine blades and the development of new alloys and catalysts.

In the United States, rhenium is a byproduct of molybdenite concentrates recovered as a byproduct of porphyry copper ore mined in the copper-molybdenum mines in the Western States. Domestic mine production data for rhenium (table 1) were derived by the U.S. Geological Survey (USGS) from reported molybdenum production at the copper-molybdenum mines. Domestic demand for rhenium metal and other rhenium products was met principally by imports but also from domestic recovery and stocks. U.S. apparent consumption of rhenium increased by about 38% from that of 2004 (table 1). Metal powder and ammonium perrhenate (APR) values were estimated to be about $1,475 and $1,225 per kilogram (kg), respectively.

Consumption

Metallurgical uses, such as in superalloys and powder metallurgy, were estimated to represent about 70% of rhenium consumption; rhenium improves the strength properties of nickel alloys at high temperatures (1,000° C). An additional 20% was used in production of reforming catalysts (Roskill Information Services Ltd., 2004, p. 46). Other uses for rhenium alloys, which collectively represented only about 10% of total consumption, were in crucibles, electrical contacts, electromagnets, electron tubes and targets, heating elements, ionization gauges, mass spectrographs, metallic coatings, temperature controls, thermocouples, semiconductors, and vacuum tubes.

Rhenium is used in petroleum-reforming catalysts for the production of high-octane hydrocarbons, which are used in the formulation of lead-free gasoline. Bimetallic platinum-rhenium catalysts have replaced many of the monometallic catalysts. Rhenium catalysts tolerate greater amounts of carbon formation when making gasoline and make it possible to operate the production process at lower pressures and higher temperatures. This leads to improved yields (production per unit of catalyst used) and higher octane ratings. Platinum-rhenium catalysts also were used in the production of benzene, toluene, and xylenes, although this use was small compared with that used in gasoline production.

Foreign Trade

Imports of metal increased sharply, about 85% (table 2), owing to strong U.S. demand, while imports of APR decreased by about 15% (table 3). Imports for consumption of rhenium metal are listed in tables 1 and 2, and those of APR are listed in tables 1 and 3.

World Review

World production of rhenium was estimated to be about 45.9 metric tons (t) (table 4). That represents the quantity of rhenium recovered from concentrates that were processed to recover rhenium values. Rhenium was recovered as a byproduct from porphyry copper-molybdenum or porphyry copper concentrates mined primarily in Armenia, Canada, Chile, Kazakhstan, Peru, Russia, the United States, and Uzbekistan. The major producers of rhenium metal and compounds were Chile, Germany, Netherlands, the United Kingdom, and the United States.

World reserves of rhenium are contained primarily in molybdenite in porphyry copper deposits. U.S. reserves of rhenium are concentrated in Arizona, Montana, Nevada, New Mexico, and Utah. Chilean reserves are found primarily at four large porphyry copper mines and in lesser deposits in the northern one-half of the country. In Peru, reserves are concentrated primarily in the Toquepala open pit porphyry copper mine and in about 12 other deposits. Other world reserves are in several porphyry copper deposits and sedimentary copper deposits in Armenia, northwestern China, Iran, Kazakhstan, Russia, and Uzbekistan and in sedimentary copper-cobalt deposits in Congo (Kinshasa). Identified U.S. resources are estimated to be about 4,500 t, and identified rest-of-the-world resources are estimated to be about 5,500 t.

Armenia.—In 2005, Yerevan Pure Iron OJSC (Yerevan) saw sales increase to $140 million from $55 million based on increased production and rising global prices. Production volume increased about 58% compared with that of 2004, as the plant produced 3,000 t of ferromolybdenum, 300 t of metallic molybdenum, and 150 kg of rhenium. The Yerevan plant received molybdenum concentrates from CJSC Zangezur Copper & Molybdenum Plant (Zangezur) in which Yerevan holds a 15% interest (Metal-Pages, 2006§[1]). The Yerevan plant's entire production was exported to Europe by Germany's Khronomet. Khronomet owns 51% of the shares in the Yerevan plant and 60% of the shares in the Zangezur plant.

Chile.—It is generally assumed that about 50% of world rhenium production comes from Chile, and that the world consumption is about 40 to 45 metric tons per year (t/yr)

[1]References that include a section mark (§) are found in the Internet References Cited section.

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(Taylor, 2002§). The leading producer of molybdenum concentrates in Chile is Corporacion Nacional del Cobre (Codelco); most of their concentrates are roasted and processed for rhenium recovery by Molibdenos y Metales S.A. (Molymet). According to industry sources, Molymet also received concentrates from two other mines in Chile and at least one in Peru. Since 2000, Molymet received rhenium-bearing residues recovered from the stacks of the roasters at its subsidiary plant, Molymex, S.A. de C.V. (Molymex), in Mexico. Molymex receives molybdenite concentrates from Grupo Mexico's La Caridad Mine and from producers in Canada, Chile, Peru, and the United States. Since 2003, Molymet also received rhenium-bearing residues from its subsidiary plant, Sadaci N.V. in Belgium, which toll roasts molybdenum concentrates from a variety of sources. The combined rhenium recovery by Molymet was estimated to be about 20.5 t in 2005.

Molymet planned to boost molybdenum concentrate processing capacity at the San Bernardo, Chile, plant by 18,000 t/yr [40 million pounds per year (Mlb/yr)] and at its Sadaci subsidiary plant in Ghent, Belgium, by 4,500 t/yr (10 Mlb/yr). The expansion in Chile was expected to be completed in mid-2007, while that in Belgium was expected to be completed in 2009. Molymet roasted molybdenum concentrates at plants in Belgium, Chile, and Mexico, and all roaster residues were sent to the San Bernardo facility for rhenium recovery (Ryan's Notes, 2004).

Kazakhstan.—Rhenium production capacity at Zhezkazganredmet (Redmet), the Kazakhstan rhenium producer, was thought to be about 1,000 kg of APR per month. Historically, Redmet received rhenium-bearing residues from the copper mine and smelter complex at Dzhezkazgan and both companies were under government control. However, after Kazakhmys Corp. bought controlling interest in Dzhezkazgan Copper Works, ownership of Redmet was in dispute. Subsequently, exports of APR from Kazakhstan were halted in the third quarter of 2005 while the dispute over control of Redmet was resolved. This action removed about 25% of world rhenium production from the market at a time when demand for superalloys in aerospace applications was increasing; as a result, the price of APR rose in the fourth quarter of 2005 (Metal-Pages, 2005§).

Current Research and Technology

Record energy prices have accelerated research and development of natural gas-to-liquid (GTL) technology. The GTL process consists of the following four stages, all which require catalysts: 1) gas cleaning, 2) reforming into syngas, 3) Fischer-Tropsch synthesis, and 4) hydrocracking (Brumby, 2005§). There are only 8 GTL plants worldwide today but as many as 30 additional plants are being considered, some starting in 2007. Many of these plants are considering a rhenium-promoted, cobalt/aluminum oxide catalyst with up to 1% rhenium content because of its increased carbon monoxide hydrogenation rate. It has been estimated that there are about 9,000 trillion cubic feet of stranded natural gas, which equates to about 900 billion barrels of synthetic liquid fuels, enough to supply about 25 years of world demand at current levels of consumption (Metal Bulletin Monthly, 2004).

Outlook

Current world demand for rhenium is likely to increase during the coming years. Demand for rhenium in nickel-base, single-crystal superalloys is estimated to account for about 60% of current world rhenium consumption. The F-35 Joint Strike Force Fighter project is projected to include production of about 3,000 aircraft and 6,000 engines using high-rhenium content superalloys. The F-22 Raptor is expected to add another 700 aircraft. These 3,700 aircraft will use 6% rhenium superalloys, while the previous generation F-16 fighter (about 4,600 aircraft) used 3% rhenium superalloys (Journal of Metals, 2004). Rhenium consumption is also expected to increase in the commercial aircraft industry as both the Boeing Company and Airbus S.A.S. are reporting record sales.

In addition to continued growth in rhenium consumption in single-crystal superalloys for use in gas engine turbine blades, increased rhenium consumption in catalysts is expected. A GTL industry with a 1-million-barrel-per-day capacity would utilize an estimated 25,000 t of catalysts (Brumby, 2005§). If only one-half of the planned GTL plants noted under Current Research and Technology are built within the next decade using rhenium-promoted catalysts, rhenium demand will probably increase by12.5 t/yr. With 125 t of rhenium in catalysts, recycling these catalysts on a 5-year interval, assuming 10% loss, could create another 2.5 t/yr of rhenium demand. This is compared with an estimated 1 t/yr of rhenium consumed by recycling catalysts in the existing petroleum reforming industry. An additional 15 t/yr of rhenium demand in a 45-t worldwide industry would severely impact the current supply-demand balance.

Perhaps the greatest potential for increased rhenium production lies in the molybdenum concentrates that are presently being roasted in facilities that are not equipped to recover the rhenium values. For instance, a significant portion of the molybdenum concentrate production of Codelco, the leading producer of molybdenum concentrates in Chile, is exported unroasted or roasted without rhenium recovery. It has been estimated that capturing lost rhenium will probably increase world rhenium production capacity by about 12 t/yr (Roskill Information Services Ltd., 2004, p. 84).

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TABLE 1
SALIENT U.S. RHENIUM STATISTICS[1]

(Kilograms, gross weight)

	2001	2002	2003	2004	2005
Supply[2]	5,500	4,000	3,900	5,900	7,100
Apparent consumption[e, 3]	28,900 [r]	20,900 [r]	18,400 [r]	26,100 [r]	36,000
Imports:					
Metal	20,200	14,300	13,200	11,800	21,800
Ammonium perrhenate	4,560	3,780	1,990	12,100	10,300

[e]Estimated. [r]Revised.
[1]Data are rounded to no more than three significant digits.
[2]Rhenium contained in molybdenite concentrates, based on calculations by the U.S. Geological Survey.
[3]Calculated as production plus imports minus exports and industry stock changes.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF RHENIUM METAL, BY COUNTRY[1]

	2004		2005	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Austria	2	$3	--	--
Belgium	8	9	--	--
Belize	--	--	34	$30
Chile	10,700	11,700	19,600	20,600
France	4	4	3	3
Germany	1,060	1,130	1,340	1,590
Netherlands	14	14	173	226
Russia	5	7	--	--
United Kingdom	4	9	544	720
Uzbekistan	--	--	50	63
Total	11,800	12,900	21,800	23,300

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau, as adjusted by the U.S. Geological Survey.

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TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF AMMONIUM PERRHENATE, BY COUNTRY[1]

	2004		2005	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Belgium	--	--	72	$50
Chile	--	--	288	265
China	666	$618	714	437
Estonia	1,500	17	60	22
France	253	321	--	--
Germany	1,660	672	1,440	1,340
Kazakhstan	4,950	4,020	4,530	2,920
Korea, Republic of	--	--	2	3
Netherlands	2,630	1,690	1,650	1,140
Poland	--	--	432	297
United Kingdom	400	226	1,110	572
Total	12,100	7,560	10,300	7,040

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau, as adjusted by the U.S. Geological Survey.

TABLE 4

RHENIUM: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Kilograms)

Country	2001	2002	2003	2004	2005
Armenia	750	800	1,000	1,000	1,200
Canada	1,700	1,700	1,700	1,700	1,700
Chile[3]	16,000 r	15,700 r	20,100 r	21,300 r	20,500
Kazakhstan	2,500	2,600	2,600	5,000 r	8,000
Peru	5,000	5,000	5,000	5,000	5,000
Russia	1,200	1,400	1,400	1,400	1,400
United States[4]	5,000 r	3,400 r	3,400 r	5,900	7,100
Uzbekistan	NA	NA	NA	NA	NA
Other	590	1,000	1,000	1,000	1,000
Total	32,700 r	31,600	36,200 r	42,300 r	45,900

rRevised. NA Not available.

[1]Estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 13, 2006.

[3]Data revised based on new information from Comisión Chilena del Cobre; also includes rhenium content from Mexico processed at Molymet in Chile.

[4]Calculated rhenium contained in molybsenite concentrates.

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World Review

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of mineral salts from seawater from first to last are calcite, gypsum, halite, astrakainite, epsomite, kainite, hexahydrite, kieserite, carnallite, and bishofite.

Saline lakewater is also processed using solar evaporation. The ponds are separated by levees that isolate the brine during different stages of fractional crystallization. The brine is circulated among a network of interconnecting ponds, with salinity increasing with each transfer. The brine is then treated with lime to remove excess calcium sulfate, pumped to evaporation ponds, and then transferred to harvesting ponds to permit the salt to crystallize. After 85% of the salt is precipitated, the remaining supernatant liquid, called "bitterns," can be pumped to adjacent ponds for subsequent extraction of bromine, magnesium, potassium, and sodium compounds. The harvesting pond is flooded again with new brine from the lime pond to repeat the cycle. It takes about 5 years once seawater is first introduced into the system for the completion of the crystallization process. The salt is harvested by special tractors equipped with scrapers and is ready for processing.

Solution Mining.—The first reported use of solution mining was about 250 B.C. in China, where holes were drilled into deep salt deposits. The brine was brought to the surface by pipes made of bamboo. The brine was evaporated over fires fueled with coal, wood, or unprocessed natural gas. The basis of current technology began in France around A.D. 858. Today, an injection well is sunk, and pressurized freshwater is introduced to hydraulically fracture the bedded salt. Once communication with the production well is established, the brine is pumped to the surface for treatment. Solution mining can also use annulus injection, which uses a pair of concentric pipes (one carries the solvent downward and the other containing the brine upward), or tubing injection, which introduces the solvent at the bottom of the tube.

Solution mining is used to obtain a sodium chloride feedstock for vacuum pan salt production and for chlorine, caustic soda, and synthetic soda ash (excluding the United States) manufacture. The quantity of underground salt dissolved and recovered as brine to make vacuum pan salt usually is not reported as primary salt production; only the quantity of vacuum pan salt manufactured is reported. The quantity of brine used to make chloralkali chemicals is reported as either the amount of captive brine used or brine sold. The chemical industry is the leading consumer of salt brine worldwide.

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Solar Salt.—After harvesting, the salt crystals are washed with dilute brine to remove residual bitterns and impurities. The salt is transferred to processing facilities where it is washed with saline water, dried for about 8 minutes at approximately 160° C (300° F), and screened into fine to coarse sizes, depending on the end use of the salt to be sold. Most operations ship solar salt in bags and in bulk, using barges, rail, and truck transportation.

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Consumption

Depending on the location, winter 2005 was either mild or severe as evidenced by many nationwide newspaper articles regarding road salt use. Some parts of the nation experienced freezing rain and sleet that required road deicing and others were blanketed with numerous snowfalls that also necessitated using large quantities of road salt (Saladin and Hansel, 2004§[1]; Jones, 2005§). Salt inventories were plentiful in many parts of the country by the end of 2005 and early 2006 in anticipation of adverse winter weather that would require large quantities of rock salt for road deicing (Cohn, 2006§).

In 2005, apparent consumption (salt sold or used plus imports minus exports) was 56.2 Mt, whereas reported consumption (sales or use as reported by the salt companies, including their imports and exports) was 53.1 Mt. Although these two measures of consumption are not necessarily expected to be identical, they normally are similar. Apparent consumption normally is greater than reported consumption because apparent consumption includes additional quantities of salt imported and exported by nonsalt-producing companies, such as some chloralkali operations and salt distributors. Reported consumption statistics are those reported only by the domestic salt producing companies.

The direct and indirect uses of salt number 14,000 according to industry sources. The USGS annually surveys 8 major categories comprising 29 end uses. The 2005 reported percentage distribution of salt by major end use was ice control, 40%; chemicals, 37%; distributors (grocery and other wholesalers and retailers, etc.), 7%; general industrial, 6%; agricultural, 3%; food processing, 3%; primary water treatment,

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TABLE 1
SALIENT U.S. RHENIUM STATISTICS[1]

(Kilograms, gross weight)

	2001	2002	2003	2004	2005
Supply[2]	5,500	4,000	3,900	5,900	7,100
Apparent consumption[e, 3]	28,900 [r]	20,900 [r]	18,400 [r]	26,100 [r]	36,000
Imports:					
Metal	20,200	14,300	13,200	11,800	21,800
Ammonium perrhenate	4,560	3,780	1,990	12,100	10,300

[e]Estimated. [r]Revised.
[1]Data are rounded to no more than three significant digits.
[2]Rhenium contained in molybdenite concentrates, based on calculations by the U.S. Geological Survey.
[3]Calculated as production plus imports minus exports and industry stock changes.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF RHENIUM METAL, BY COUNTRY[1]

	2004		2005	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Austria	2	$3	--	--
Belgium	8	9	--	--
Belize	--	--	34	$30
Chile	10,700	11,700	19,600	20,600
France	4	4	3	3
Germany	1,060	1,130	1,340	1,590
Netherlands	14	14	173	226
Russia	5	7	--	--
United Kingdom	4	9	544	720
Uzbekistan	--	--	50	63
Total	11,800	12,900	21,800	23,300

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau, as adjusted by the U.S. Geological Survey.

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TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF AMMONIUM PERRHENATE, BY COUNTRY[1]

	2004		2005	
Country	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
Belgium	--	--	72	$50
Chile	--	--	288	265
China	666	$618	714	437
Estonia	1,500	17	60	22
France	253	321	--	--
Germany	1,660	672	1,440	1,340
Kazakhstan	4,950	4,020	4,530	2,920
Korea, Republic of	--	--	2	3
Netherlands	2,630	1,690	1,650	1,140
Poland	--	--	432	297
United Kingdom	400	226	1,110	572
Total	12,100	7,560	10,300	7,040

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau, as adjusted by the U.S. Geological Survey.

TABLE 4

RHENIUM: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Kilograms)

Country	2001	2002	2003	2004	2005
Armenia	750	800	1,000	1,000	1,200
Canada	1,700	1,700	1,700	1,700	1,700
Chile[3]	16,000 r	15,700 r	20,100 r	21,300 r	20,500
Kazakhstan	2,500	2,600	2,600	5,000 r	8,000
Peru	5,000	5,000	5,000	5,000	5,000
Russia	1,200	1,400	1,400	1,400	1,400
United States[4]	5,000 r	3,400 r	3,400 r	5,900	7,100
Uzbekistan	NA	NA	NA	NA	NA
Other	590	1,000	1,000	1,000	1,000
Total	32,700 r	31,600	36,200 r	42,300 r	45,900

rRevised. NA Not available.

[1]Estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 13, 2006.

[3]Data revised based on new information from Comisión Chilena del Cobre; also includes rhenium content from Mexico processed at Molymet in Chile.

[4]Calculated rhenium contained in molybsenite concentrates.

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SALT

By Dennis S. Kostick

Domestic survey data and tables were prepared by Jeffrey A. Milanovich, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Total U.S. salt production in 2005 decreased by 3% to 45.1 million metric tons (Mt) compared with that of 2004 (table 1). According to the U.S. Geological Survey (USGS) canvass for 2005, 29 companies operated 64 salt-producing plants in 15 States. Of these, 11 companies and 16 plants produced more than 1 Mt each and accounted for 92% and 60%, respectively, of total U.S. production and 91% and 37%, respectively, of total value. Several companies and plants produced more than one type of salt. In 2005, 14 companies (30 operations) produced salt brine; 11 companies (15 operations), rock salt; 9 companies (12 operations) produced solar-evaporated salt; and 6 companies (17 operations), vacuum pan salt.

The five leading States were, in descending order of total salt sold or used, Louisiana with 31%; Texas, 21%; New York, 15%; Kansas, 6%; and Utah, 5%. Other Eastern States (Alabama, Michigan, Ohio, Tennessee, and West Virginia) accounted for 19% of the domestic total salt sold or used. Other Western States (Arizona, California, Nevada, New Mexico, and Oklahoma) represented 3% (table 4).

Salt, also known as sodium chloride, comprises the elements sodium and chlorine. Sodium is a silver-colored metal that is so unstable that it reacts violently in the presence of water, and chlorine is a greenish-colored gas that is dangerous and may be lethal. Yet the combination of these two elements form sodium chloride, which is a white-colored compound essential to life itself. Virtually every person in the world has some direct or indirect contact with salt daily. People routinely add salt to their food as a flavor enhancer or apply rock salt to walkways to remove ice in the winter. Salt is used as feedstock for chlorine and caustic soda manufacture. These two inorganic chemicals are used to make many consumer-related end-use products, such as polyvinyl chloride (PVC), a plastic made from chlorine, and paper-pulping chemicals manufactured from sodium hydroxide (caustic soda).

Production

U.S. production and sales data for salt are developed by the USGS from an annual voluntary canvass of U.S. salt-producing sites and company operations. Production refers to the quantity of salt mined or manufactured that is available for sale. Salt sold or used is the quantity of salt that was sold directly to customers or used by the salt producer, which usually is a chloralkali (chlorine and sodium hydroxide) manufacturer.

Of the 29 companies to which a canvass form was sent, all but 2 responded, representing 14% of the totals shown in this report. Data for the nonrespondents were estimated based on their prior responses to previous annual surveys, the 2005 production estimate survey, or brine production capabilities for chloralkali manufacture based upon published chlorine production capacities [1.75 metric tons (t) of salt required per ton of chlorine capacity].

The structure of the U.S. salt industry has changed throughout the years. In 1970, 50 companies operated 95 salt-producing plants in the United States. Market competition, increased energy and labor costs, less expensive imports, fluctuations in currency exchange rates, and an excess of production capacity (resulting in the downsizing of the industry through mergers and acquisitions) reduced the number of operations in the industry to 29 companies and 64 plants by 2005.

The four types of salt that are surveyed are classified according to the method of recovery as follows: rock salt, from the surface or underground mining of halite deposits; solar salt, from the solar evaporation of seawater, landlocked bodies of saline water, or primary or byproduct brines; vacuum pan salt, from the mechanical evaporation of a purified brine feedstock; and brine, from the solution mining of underground halite deposits. Data for brine production and consumption represent the anhydrous salt content only and not the weight of the water.

***Mining.*—Rock Salt.**—Rock salt is mined by the room-and-pillar method, which is similar to that used in coal and trona mining. The pillar widths are controlled by the percentage of extraction permissible at the various depths and room widths. Most room-and-pillar operations recover 45% to 65% of the resource, with the remainder left behind as pillar supports for structural integrity of the mine. The salt is drilled, cut, blasted, mucked, crushed, and transported to the surface for processing, which usually involves removing the impurities and screening the material to finer size fractions.

Underground mining practices of bedded halite (commonly referred to as "rock salt") and domal salt formations are similar except for the height differences within the mines of the two types of operations. For example, bedded formations usually are laterally extensive but are vertically restricted. Salt domes are laterally restrictive but are vertically extensive. Some salt domes have depths in excess of 6,100 meters (m) (20,000 feet), whereas others crop out at the surface. The tops of Gulf Coast salt mining operations are generally less than 300 m (1,000 feet) below the surface. Working at greater depths is difficult because of higher temperatures and denser rock.

Solar Evaporation.—Solar evaporation uses the wind and the sun to evaporate the water and is an effective method of producing solar salt in areas of high evaporation and low precipitation. Along coastal margins in many parts of the world, seawater is collected and allowed to evaporate in specially constructed concentrating and evaporating ponds. Seawater contains various dissolved salts that will separate depending on their relative solubilities. Calacite (calcium carbonate), which is the least soluble, will crystallize out first. Highly soluble magnesium salts tend to crystallize last. The order of separation

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of mineral salts from seawater from first to last are calcite, gypsum, halite, astrakainite, epsomite, kainite, hexahydrite, kieserite, carnallite, and bishofite.

Saline lakewater is also processed using solar evaporation. The ponds are separated by levees that isolate the brine during different stages of fractional crystallization. The brine is circulated among a network of interconnecting ponds, with salinity increasing with each transfer. The brine is then treated with lime to remove excess calcium sulfate, pumped to evaporation ponds, and then transferred to harvesting ponds to permit the salt to crystallize. After 85% of the salt is precipitated, the remaining supernatant liquid, called "bitterns," can be pumped to adjacent ponds for subsequent extraction of bromine, magnesium, potassium, and sodium compounds. The harvesting pond is flooded again with new brine from the lime pond to repeat the cycle. It takes about 5 years once seawater is first introduced into the system for the completion of the crystallization process. The salt is harvested by special tractors equipped with scrapers and is ready for processing.

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2%; and other uses combined with exports, 2% (table 5). Distributors represented a substantial share of salt sales by the salt industry; all this salt is ultimately resold to many different end users. For a more complete analysis of end-use markets, specific sectors of distribution in table 5 can be combined, such as agricultural and water treatment with agricultural and water conditioning distribution, respectively.

Aside from the different types of salt, there are various distinctions in the packaging and applications of salt. Salt for human consumption is packaged in different sized containers for several specialized purposes. Table salt may contain 0.01% potassium iodide as an additive, which provides a source of iodine that is essential to the oxidation processes in the body. Kosher salt, sea salt, condiment salt, and salt tablets are special varieties of salt.

Chemical Industry.—The leading consumer of salt, primarily salt brine, is the chemical industry. Salt brine is extracted from natural underground saline sources, solution-mined halite deposits (salt beds or salt domes), or the dissolution of solar salt supplies. Within this industry, the chloralkali sector remains the major consumer of salt for manufacturing chlorine, coproduct sodium hydroxide, and synthetic soda ash. Since 1986, when the last synthetic soda ash plant closed because of high production costs and competition with less expensive natural soda ash, no synthetic soda ash has been manufactured in the United States; many countries, however, still produce synthetic soda ash and use vast quantities of salt brine as feedstock.

Salt is used as the primary raw material in chlorine manufacture because it is an inexpensive and widely available source of chlorine ions. For sodium hydroxide production, salt is the main source of sodium ions. Of the domestic chlorine and sodium hydroxide produced, 98% is obtained from the electrolysis of salt brine feedstock by using three-cell technologies. The types of cells and the percentages of chlorine manufactured by them are diaphragm, 78%; mercury, 14%; and membrane, 6%. The remaining 2% of chlorine and caustic soda production is recovered as a byproduct from magnesium and sodium metal manufacture. It takes 1.75 t of salt to make 1.0 t of chlorine and 1.1 t of coproduct caustic soda. The electrolytic process ionizes the sodium chloride compound and selectively allows the ions to migrate through special membranes. Chlorine gas forms at the anode, while sodium ions bond with water molecules at the cathode to form sodium hydroxide with hydrogen gas evolving.

Chlorine and caustic soda are considered to be the first generation of products made from salt. These two chemicals are further used to manufacture other materials, which are considered to be the second generation of products from salt. Although most salt brine is produced by the same companies that use it, many chloralkali manufacturers now purchase brine from independent brine supply companies. In certain cases, brine is produced by a chemical company that uses some of it and sells the excess to neighboring competitors. According to a survey of domestic salt-base chlorine facilities, 48% of the salt used to manufacture chlorine was captive (produced by manufacturing companies), and 31% was purchased brine. Purchased solar salt and rock salt comprised 12%, and imported rock, solar, and vacuum pan salt was 9% (tables 5, 6).

In 2005, according to the U.S. Census Bureau, 10.3 Mt of chlorine and 8.5 Mt of sodium hydroxide (caustic soda or lye) were produced. Based on the industry average ratio of 1.75 t of salt required to produce 1.0 t of chlorine and 1.1 t of coproduct sodium hydroxide, the chlorine and caustic soda industry consumed 18 Mt of salt for feedstock. Reported consumption of total domestic and imported salt for chlorine manufacture was 18.4 Mt (table 5). The difference between the calculated and reported quantities was the amount of salt not reported to the USGS from imports or captive brine production of chloralkali producers.

Salt is also used as a feedstock in chemical plants that make sodium chlorate (by the electrolysis of an acidified salt brine using hydrochloric acid adjusted to a pH of 6.5), metallic sodium (by the electrolysis of a molten salt mixture containing 33.2% sodium chloride and 66.8% calcium chloride, which is added to reduce the melting temperature of salt), and other downstream chemical operations. In powdered soaps and detergents, salt is used as a bulking agent and a coagulant for colloidal dispersion after saponification. In pharmaceuticals, salt is a chemical reagent and is used as the electrolyte in saline solutions. It is used also with sulfuric acid to produce sodium sulfate and hydrochloric acid. This subsector is relatively small, representing only 5% of domestic salt sales for the entire chemical sector and only 2% of total domestic salt consumption.

The consumption of salt for metallic sodium has declined during the past several years. Since the 1970s, the number of producers has decreased to one from three; Ethyl Corp. and RMI Titanium Corp. exited the market in 1985 and 1992, respectively, leaving E.I. du Pont de Nemours & Co., Inc. as the sole manufacturer of metallic sodium in the United States. In 1998, the domestic market for metallic sodium was less than 30,000 t, having decreased from 126,000 t in 1978. The phasing out of tetraethyl lead and tetramethyl lead gasoline antiknock additives was the main reason for the decline in consumption. The method for making tetraalkyl lead involved the alkylation of a lead-sodium alloy with either ethyl chloride or methyl chloride. The alkyl chloride is introduced into a reactor containing the lead-sodium alloy. After the reaction is completed, the remaining alkyl chloride is vented and the product recovered.

In 1978, sodium usage in gasoline represented 80% of the domestic market. Although there is no information about sodium consumption in 2005, the leading use of sodium in 1998 was for sodium borohydride production, which is the feedstock for sodium dithionite that is used as a reductive bleaching agent by the pulp and paper industry. Sodium for sodium borohydride manufacture accounted for 38% of metallic sodium consumption. Sodium metal also is used to manufacture sodium azide, which is used in automotive air bags. Other promising uses of sodium metal are in the remediation of chemical weapons, chlorofluorocarbons, pesticides, and polychlorinated biphenyls.

Ice Control and Road Stabilization.—The second-ranked end use of salt is for highway deicing. The developer of the Fahrenheit temperature scale discovered that salt mixed with ice at a temperature below the freezing point of water creates a solution (brine) with a lower freezing point than water alone.

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The brine forms below the surface of the ice and snow and prevents the water from freezing into ice and bonding with the road surface, thus causing the snow and ice to melt. Salt is an inexpensive, widely available, and effective ice control agent. It does, however, become less effective as the temperature decreases below 6.5° C to 9.5° C (15° F to 20° F). At lower temperatures, more salt would have to be applied to maintain higher brine concentrations to provide the same degree of melting. Most winter snowstorms and ice storms happen when temperatures are between 4° C and 0° C (25° F and 32° F), the range in which salt is most effective. An anticaking agent, such as ferric ferrocyanide (Prussian Blue) or sodium ferrocyanide (Yellow Prussiate of Soda), is used to prevent the salt from agglomerating. Both additives are nontoxic and harmless to humans. In fact, sodium ferrocyanide is approved for use in food-grade salt by the U.S. Food and Drug Administration (U.S. Department of Health and Human Services, U.S. Food and Drug Administration, Food and Nutrition Board, 1966).

In highway deicing, salt has been associated with corrosion of bridge decks, motor vehicles, reinforcement bar and wire, and unprotected steel structures used in road construction. Surface runoff, vehicle spraying, and windblown actions also affect soil, roadside vegetation, and local surface water and ground water supplies. Although evidence of environmental loading of salt has been found during peak usage, the spring rains and thaws usually dilute the concentrations of sodium in the area where salt was applied.

Salt also is added to stabilize the soil and to provide firmness to the foundation on which highways are built. The salt acts to minimize the effects of shifting caused in the subsurface by changes in humidity and traffic load.

The quantity of salt consumed for road deicing each year is directly related to the severity of the winter weather conditions. Long-range forecasting of salt consumption in this application is extremely difficult because of the complexities in long-range forecasting of the weather. Meteorologists, however, are becoming more aware of the dynamics of certain weather phenomena that influence the climate in various parts of the world. One of these phenomena is El Niño, an increase in sea-surface temperatures in the equatorial Pacific Ocean, is now thought to be the leading weather influence on Earth.

Distributors.—A tremendous amount of salt is marketed through various distributors, some of which specialize in agricultural and water treatment services, two sectors in which the salt companies also have direct sales (table 5). Distributor sales also include grocery wholesalers and/or retailers, institutional wholesalers, U.S. Government resale, and other wholesalers and retailers.

General Industrial.—The industrial uses of salt are diverse. They include, in descending order of quantity consumed, oil and gas exploration, other industrial applications, textiles and dyeing, metal processing, pulp and paper, tanning and leather treatment, and rubber manufacture.

In oil and gas exploration, salt is an important component of drilling fluids in well drilling. It is used to flocculate and increase the density of the drilling fluid to overcome high downwell gas pressures. Whenever a drill hits a salt formation, salt is added to the drilling fluid to saturate the solution and to minimize the dissolution within the salt stratum. Salt is also used to increase the set rate of concrete in cemented casings.

In textiles and dyeing, salt is used as a brine rinse to separate organic contaminants, to promote "salting out" of dyestuff precipitates, and to blend with concentrated dyes to standardize them. One of its main roles is to provide the positive ion charge to promote the absorption of negatively charged ions of dyes.

In metal processing, salt is used in concentrating uranium ore into uranium oxide (yellow cake). It also is used in processing aluminum, beryllium, copper, steel, and vanadium.

In the pulp and paper industry, salt is used to bleach wood pulp. It also is used to make sodium chlorate, which is added along with sulfuric acid and water to manufacture chlorine dioxide, an excellent oxygen-base bleaching chemical. The chlorine dioxide process, which originated in Germany after World War I, is becoming more popular because of environmental pressures to reduce or eliminate chlorinated bleaching compounds.

In tanning and leather treatment, salt is added to animal hides to inhibit microbial activity on the underside of the hides and to attract moisture back into the hides. In rubber manufacture, salt is used to make buna, neoprene, and white types. Salt brine and sulfuric acid are used to coagulate an emulsified latex made from chlorinated butadiene.

Agricultural Industry.—Since prehistoric times, humankind has noticed that animals satisfied their salt hunger by locating salt springs, salt licks, or playa lake salt crusts. Barnyard and grazing livestock need supplementary salt rations to maintain proper nutrition. Veterinarians advocate adding loose salt in commercially mixed feeds, or in block forms sold to farmers and ranchers, because salt acts as an excellent carrier for trace elements not found in the vegetation consumed by grazing livestock; selenium, sulfur, and other essential elements are commonly added to salt licks, or salt blocks, for free-choice feeding.

Animal feed and water conditioning salt are made into 22.7-kilogram (50-pound) pressed blocks. Iodine, sulfur, trace elements, and vitamins are occasionally added to salt blocks to provide nutrients not found naturally in the diet of certain livestock. Salt is also compressed into pellets that are used for water conditioning.

Food Processing.—Every person uses some quantity of salt in their food. The salt is added to the food by the food processor or by the consumer as a flavor enhancer, preservative, binder, fermentation-control additive, texture-control agent, and color developer. This major category is subdivided, in descending order of salt consumption, into other food processing, meat packers, canning, baking, dairy, and grain mill products.

In meat packing, salt is added to processed meats to promote color development in bacon, ham, and other processed meat products. As a preservative, salt inhibits the growth of bacteria, which would lead to spoilage of the product. Early pioneers stored their perishable food in salt barrels for protection and preservation. Salt acts as a binder in sausages to form a binding gel made up of meat, fat, and moisture. Salt also acts as a flavor enhancer and as a tenderizer.

In the dairy industry, salt is added to cheese as a color-, fermentation-, and texture-control agent. The dairy subsector

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includes companies that manufacture creamery butter, condensed and evaporated milk, frozen desserts, ice cream, natural and processed cheese, and specialty dairy products.

In canning, salt is primarily added as a flavor enhancer and preservative. It also is used as a carrier for other ingredients, dehydrating agent, enzyme inhibitor, and tenderizer.

In baking, salt is added to control the rate of fermentation in bread dough. It also is used to strengthen the gluten (the elastic protein-water complex in certain doughs) and as a flavor enhancer, such as a topping on baked goods.

The food-processing category also contains grain mill products, which consist of milling flour and rice and manufacturing cereal breakfast food and blended or prepared flour.

In the "other food processing" category, salt is used mainly as a seasoning agent. This category includes miscellaneous establishments that make food for human consumption (such as potato chips and pretzels) and for domestic pet consumption (such as cat and dog food).

Water Treatment.—Many areas of the United States have hard water, which contains excessive calcium and magnesium ions that contribute to the buildup of a scale or film of alkaline mineral deposits in household and industrial equipment and pipes. Commercial and residential water-softening units use salt to remove the ions that cause the hardness. The sodium ions captured on a resin bed are exchanged for the calcium and magnesium ions. Periodically, the water-softening units must be recharged because the sodium ions become depleted. Salt is added and dissolved, and brine replenishes the lost sodium ions.

Stocks

Because bulk salt is stored at many different locations, such as plants, ports, terminals, and warehouses, data on the quantity of salt stockpiled by the salt industry are not reliable enough to formulate accurate inventory totals; however, yearend stocks of producers were estimated to be 2 Mt, and consumer inventories also were estimated to be high. Most of these inventories were imported rock salt and solar salt. Many salt distributors, municipalities, road deicing contractors, salt producers, and States stockpiled additional quantities of salt in anticipation of adverse weather conditions. Deicing salt inventories were extremely large by yearend 2005 in anticipation of severe winter weather during late 2005 to early 2006. For the reasons discussed above, salt stocks are assumed to be the difference between salt production and salt sold or used in calculating apparent consumption.

Transportation

Because the locations of the salt supplies are not often near consumers, transportation may be an important cost. Pumping salt brine through pipelines is an economic means of transportation but cannot be used for dry salt. Large bulk shipments of dry salt in ocean freighters or river barges are low in cost but are restricted in points of origin and consumption. River and lake movement of salt in winter is often severely curtailed because of frozen waterways. As salt is packaged, handled, and shipped in smaller units, the costs increase and are reflected in higher selling prices.

Transportation costs significantly add to the price of salt. In some cases, shipping costs are higher than the actual value of the salt. Ocean vessels can transport greater quantities of salt than barge, rail, or truck shipments. Transoceanic imports of salt have been increasing in some areas of the United States because they are more cost competitive than salt purchased from domestic suppliers using barge, rail, or truck transportation. One important factor that often determines the quantity of salt that can be imported is the depth of the channels and the ports; many ports are not deep enough to accommodate larger ships.

Prices

The four types of salt that are produced have unique production, processing, and packaging factors that determine the selling prices. Generally, salt sold in bulk is less expensive than salt that has been packaged, pelletized, or pressed into blocks. Salt in brine is the least expensive salt sold because mining and processing costs are less. Vacuum pan salt is the most expensive because of the higher energy costs involved in processing and the purity of the product.

Price quotations are not synonymous with average values reported to the USGS. The quotations do not necessarily represent prices at which transactions actually took place or bid and asked prices. Yearend prices for salt are no longer quoted in Chemical Market Reporter; this information was last available for 1997. The average annual values, as collected by the USGS and listed in table 7, represent a national average value for each of the types of salt and the various product forms.

Foreign Trade

Under Harmonized Tariff Schedule of the United States (HTS) nomenclature, imports are aggregated under one category named "Salt (including table and denatured salt) and pure sodium chloride, whether or not in aqueous solution, seawater." The same classification also applies to exports. The HTS code for salt is 2501.00.0000. The trade tables in this report list the previous and current identification codes for salt. Although several other HTS codes pertain to various salt classifications, the United States aggregates shipments under one code because the sums of individual subclassifications fail to meet the minimum dollar requirements necessary for individual listings.

Based on U.S. Census Bureau data for 2005, the United States exported 879,000 t; this was a 21% decrease compared with that of 2004 (table 8). In 2005, the majority of exports (78%) were to Canada. Salt was shipped to 69 countries through 31 customs districts; the Cleveland, OH, district exported the most and represented 42% of the U.S. total (table 9). Based on U.S. Census Bureau statistics, the United States imported 12.1 Mt of salt from 52 countries in 2005, which was slightly more than was imported during 2004 (table 10). Canada was the leading source of imports, representing 33% of total imports, followed by Chile (32%), the Bahamas (11%), and Mexico (8%). Table 11 lists the imports of salt by customs districts. Of the 39 customs districts that imported salt in 2005, the New York, NY, customs district was the largest in terms of tonnage, accounting

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for 20% of the total. The quantity of imported salt was 14 times more than that of exports. This indicates the magnitude of the United States' reliance on salt imports. The majority of imported salt was brought into the country by foreign subsidiaries of major U.S. salt producers. Generally, imported salt can be purchased and delivered to many U.S. customers at prices lower than the comparable domestic product because production costs are lower abroad, currency exchange rates may favor the price of imported salt rather than the price of domestic salt, and ocean freight rates are less expensive than overland rail or truck rates.

World Industry Structure

Table 12 lists world salt production statistics for 115 nations based on reported and estimated information. In 2005, the total estimated world production increased to 238 Mt. The United States remained the world's leading salt-producing country, representing 19% of total world output. China is rapidly increasing its production. In 2005, estimated salt production in China was 44.5 Mt, which makes it the second-ranked salt producer in the world.

Most countries possess some form of salt production capability, with production levels set to meet their own domestic demand requirements and with additional quantities available for export to many countries. Many developing nations tend to develop their agricultural resources to feed their population first. Utilization of easily extractable mineral resources follows, and salt is one of the first mineral commodities to be mined. Some countries, such as the United States, import a substantial amount of salt to meet total demand requirements because of economic factors, as previously discussed.

World Review

China.—China is the world's leading producer of synthetic soda ash, which uses large quantities of salt as feedstock. Although China's chloralkali industry is concentrated in the eastern Provinces where most of the population and salt resources are located, many of the salt operations have not been able to keep up with the strong demand created by the rise in soda ash production. Salt deposits in the central and western Provinces cannot be utilized because of overland transportation difficulties, so China has had to rely on salt imports from Australia and India to satisfy its supply requirements. These two nations may not be able to supply China for long if its salt requirement continues to grow. It is expected that there will be a salt shortage in China for the next few years (Asian Chemical News, 2005).

Sri Lanka.—Aside from the tremendous toll on human lives, the large tsunami that devastated many areas of Southeast Asia on December 26 inundated thousands of rice farms, fruit plantations, and drinking-water wells with salt water. Salt crusts formed on the fields as the seawater evaporated, and saline water infiltrated the soils and contaminated many underground freshwater aquifers. Agricultural officials in Sri Lanka estimated that it would take a decade for the lands to be restored to farming again. Many coastal villages have become dependent on outside assistance for food and water. Similar salt contamination problems affected other Indian Ocean islands, such as the Maldives, and Indonesia (Pearce, 2005§).

United Kingdom.—Compass Minerals International Inc. announced plans near yearend 2005 to sell its British subsidiary (Salt Union Ltd.) to Ineos Enterprises. The salt operation produces vacuum pan salt in Weston Point, Cheshire. Ineos is the supplier of salt brine to the salt plant (Chemical Market Reporter, 2005).

Outlook

The U.S. salt industry continued in a positive direction of increased production, consumption, and world trade of salt. Despite the closing and idling of some chlorine plants during the previous several years, remaining chlorine facilities have run at higher capacity utilization rates, thereby offsetting any change in salt brine production and consumption. Because the chloralkali industry is energy-intensive, any increase in energy prices will have an adverse effect on chlorine manufacture and a corresponding effect on salt brine usage. Solar salt and vacuum pan salt production and consumption have been consistent, and the outlook is favorable for this trend to continue. Rock salt production and consumption are heavily dependent on the severity of winter weather. Although the severity of the weather is virtually impossible to forecast far in advance, the supplies of salt, from either domestic or imported sources, are more than adequate to meet any anticipated increase in demand.

Because salt is a relatively low-value commodity, the shipping cost for oceanic, rail, or truck transportation can be an important determining factor when attempting to secure supply sources from either domestic or foreign locations. If energy prices increase, one mode of transportation may favor one over the others. Excluding deicing salt, domestic salt consumption may fluctuate but will probably continue to grow parallel to population growth trends. U.S. total salt production in 2006 is expected to be an estimated 45 Mt.

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TABLE 1
SALIENT SALT STATISTICS[1]

(Thousand metric tons and thousand dollars)

	2001	2002	2003	2004	2005
United States:					
Production:[2]					
Brine	20,400	19,300	20,000	20,500	19,900
Rock	17,000	13,500	16,300	18,300	17,700
Solar	3,310	3,390	3,330	3,520	3,430
Vacuum and open pans	4,120	4,100	4,070	4,100	4,170
Total	44,800	40,300	43,700	46,500	45,100
Sold or used by producers:					
Quantity	42,200	37,700	41,100	45,000	45,000
Value	1,110,000	1,010,000	1,130,000	1,270,000	1,310,000
Exports:					
Quantity	1,120	689	718	1,110	879
Value	48,000	31,600	37,500	47,600	51,800
Imports for consumption:					
Quantity	12,900	8,160	12,900	11,900	12,100
Value	179,000	129,000	196,000	159,000	180,000
Consumption:					
Apparent[3]	54,000	45,100	53,200	55,800	56,200
Reported	48,700	43,600	50,200	50,700 r	53,100
World, production	214,000 r	212,000 r	218,000 r	229,000 r	238,000 e

eEstimated. rRevised.
[1]Data are rounded to no more than three significant digits.
[2]Excludes Puerto Rico.
[3]Sold or used plus imports minus exports.

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TABLE 2
SALT PRODUCED IN THE UNITED STATES, BY TYPE AND PRODUCT FORM[1]

(Thousand metric tons)

Product form	Vacuum and open pans	Solar	Rock	Brine	Total
2004:					
Bulk	728	2,170	17,800	20,500	41,200
Compressed pellets	1,310	391	XX	XX	1,710
Packaged	1,900	811	459	XX	3,170
Pressed blocks	167	147	81	XX	394
Total	4,100	3,520	18,300	20,500	46,500
2005:					
Bulk	793	2,000	17,300	19,900	39,900
Compressed pellets	1,340	392	XX	XX	1,740
Packaged	1,880	876	355	XX	3,110
Pressed blocks	156	155	78	XX	388
Total	4,170	3,430	17,700	19,900	45,100

XX Not applicable.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 3
SALT SOLD OR USED IN THE UNITED STATES, BY TYPE AND PRODUCT FORM[1, 2]

(Thousand metric tons and thousand dollars)

	Vacuum and open pans		Solar		Rock		Brine		Total	
Product form	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
2004:										
Bulk	718	44,800	1,600	37,200	16,900	408,000	20,500	144,000	39,700	634,000
Compressed pellets	1,330	184,000	364	41,800	XX	XX	XX	XX	1,700	226,000
Packaged:										
Less-than-5-pound units	218	NA	8	NA	(3)	NA	XX	XX	227	XX
More-than-5-pound units	1,610	NA	945	NA	455	NA	XX	XX	3,010	XX
Total	1,830	269,000	953	64,400	456	39,000	XX	XX	3,240	372,000
Pressed blocks:										
For livestock	102	NA	107	NA	75	NA	XX	XX	284	XX
For water treatment	63	NA	25	NA	5	NA	XX	XX	93	XX
Total	165	17,400	131	12,300	81	8,340	XX	XX	377	38,000
Grand total	4,040	515,000	3,040	156,000	17,400	456,000	20,500	144,000	45,000	1,270,000
2005:										
Bulk	751	53,500	1,520	41,400	17,700	438,000	19,800	139,000	39,800	672,000
Compressed pellets	1,340	192,000	372	46,600	XX	XX	XX	XX	1,710	238,000
Packaged:										
Less-than-5-pound units	204	NA	9	NA	(3)	NA	XX	XX	213	XX
More-than-5-pound units	1,530	NA	1,000	NA	357	NA	XX	XX	2,890	XX
Total	1,730	254,000	1,010	80,600	357	28,900	XX	XX	3,100	364,000
Pressed blocks:										
For livestock	96	NA	111	NA	73	NA	XX	XX	280	XX
For water treatment	57	NA	26	NA	4	NA	XX	XX	86	XX
Total	152	16,700	137	14,100	78	8,640	XX	XX	367	39,400
Grand total	3,970	516,000	3,040	183,000	18,100	475,000	19,800	139,000	45,000	1,310,000

NA Not available. XX Not applicable.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]As reported at salt production locations, the term "sold or used" indicates that some salt, usually salt brine, is not sold but is used for captive purposes by plant or company. Because data do not include salt imported, purchased, and/or sold from inventory from regional distribution centers, salt sold or used by type may differ from totals shown in tables 5 and 6, which are derived from company totals.

[3]Less than ½ unit.

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TABLE 4
SALT SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1, 2]

(Thousand metric tons and thousand dollars)

State	2004		2005	
	Quantity	Value	Quantity	Value
Kansas	2,890	127,000	2,890	135,000
Louisiana	14,300	186,000	13,800	182,000
New York	6,430	301,000	6,840	327,000
Texas	9,780	118,000	9,600	118,000
Utah	2,250	107,000	2,250	132,000
Other Eastern States[3]	8,090	360,000	8,400	347,000
Other Western States[4]	1,250	71,200	1,250	73,500
Total	45,000	1,270,000	45,000	1,310,000
Puerto Rico[e]	45	1,500	45	1,500

[e]Estimated.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]The term "sold or used" indicates that some salt, usually salt brine, is not sold but is used for captive purposes by plant or company.

[3]Includes Alabama, Michigan, Ohio, Tennessee, and West Virginia.

[4]Includes Arizona, California, Nevada, New Mexico, and Oklahoma.

TABLE 5
DISTRIBUTION OF DOMESTIC AND IMPORTED SALT BY PRODUCERS IN THE UNITED STATES BY END USE AND TYPE[1, 2]

(Thousand metric tons)

End use	Standard industrial classification	Vacuum and open pans		Solar		Rock		Brine		Total[3]	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Chemical:											
Chloralkali producers	2812	18	17	315	301	714 r	514	18,200	17,600	19,200	18,400
Other chemical	28 (excludes 2812, 2899)	260 r	274	207 r	219	773 r	689	2	78	1,240 r	1,260
Total		278 r	291	522 r	519	1,490 r	1,200	18,200	17,700	20,400 r	19,700
Food-processing industry:											
Meat packers	201	243 r	260	53 r	62	89 r	76	--	--	385 r	398
Dairy	202	119 r	122	9	8	3	3	--	--	131 r	134
Canning	2091, 203	149 r	141	36 r	33	39 r	36	1	(4)	225	211
Baking	205	192 r	187	4 r	4	12	13	--	--	209 r	204
Grain mill products	204 (excludes 2047)	90 r	89	7	6	14	19	--	--	110 r	133
Other food processing	206-208, 2047, 2099	562 r	584	78	74	96	75	1	2	737 r	736
Total		1,350 r	1,380	187 r	187	252 r	222	2	3	1,800 r	1,800
General industrial:											
Textiles and dyeing	22	102 r	107	33 r	32	10 r	10	(4)	(4)	145 r	149
Metal processing	33, 34, 35, 37	12 r	12	23 r	20	78 r	74	(4)	(4)	112 r	107
Rubber	2822, 30 (excludes 3079)	3	3	1	(4)	2	1	64	60	69	65
Oil	13, 29	33 r	31	191 r	190	49 r	46	2,070	1,940	2,350 r	2,210
Pulp and paper	26	10	9	44 r	41	14 r	13	18	17	86 r	81
Tanning and/or leather	311	9 r	9	13 r	11	35	35	--	--	56 r	55
Other industrial	XX	130	131	92 r	63	489 r	150	1	(4)	712 r	344
Total		300	302	396 r	357	677 r	330	2,160	2,020	3,530 r	3,010

See footnotes at end of table.

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TABLE 5—Continued

DISTRIBUTION OF DOMESTIC AND IMPORTED SALT BY PRODUCERS IN THE UNITED STATES BY END USE AND TYPE[1, 2]

(Thousand metric tons)

End use	Standard industrial classification	Vacuum and open pans		Solar		Rock		Brine		Total[3]	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Agricultural:											
Feed retailers and/or dealers mixers	5159	317 r	326	367 r	391	407	426	--	(4)	1,090	1,140
Feed manufacturers	2048	41 r	41	128 r	132	283	304	--	--	451 r	477
Direct-buying end user	02	4	4	16 r	13	25 r	22	--	--	45 r	38
Total		362 r	371	511 r	536	715 r	753	--	(4)	1,590 r	1,660
Water treatment:											
Government (Federal, State, local)	2899	18 r	17	108 r	321	126 r	134	3 r	3	255 r	476
Commercial or other	2899	162	169	246 r	335	192 r	152	3 r	8	603 r	664
Total		180 r	186	354 r	656	318 r	287	6 r	11	858 r	1,140
Ice control and/or stabilization:											
Government (Federal, State, local)	9621	1	1	857 r	948	14,700 r	17,300	--	--	15,600 r	18,200
Commercial or other	XX	5	7	211 r	175	2,170 r	2,560	--	--	2,380 r	2,740
Total		6	8	1,070 r	1,120	16,900 r	19,800	--	--	18,000 r	21,000
Distributors:											
Agricultural distribution	5191	70 r	68	114 r	106	57	53	--	--	242 r	227
Grocery wholesalers and/or retailers	514, 54	513 r	513	215	234	66 r	57	--	--	794 r	803
Institutional wholesalers and end users	58, 70	108 r	108	55 r	64	49	55	(4)	(4)	212 r	228
Water-conditioning distribution	7399	118	119	369	358	26	33	1	1	514	511
U.S. Government resale	9199	(4)	(4)	(4)	1	1	1	--	--	1	1
Other wholesalers and/or retailers	5251	904 r	876	917 r	938	373 r	374	9	10	2,200 r	2,200
Total		1,710	1,680	1,670 r	1,700	572 r	573	10	11	3,970 r	3,970
Other[5]		101 r	96	33 r	115	472 r	436	125	238	731 r	885
Grand total		4,300 r	4,320	4,740 r	5,190	21,400 r	23,600	20,300	20,000	50,700 r	53,100

rRevised. XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]The quantity of imports included in the total for each type of salt is the amount reported by the U.S. salt industry, not the quantity reported by the U.S. Census Bureau that appears in tables 1, 11, and 12.

[3]Because data include salt imported, produced, and/or sold from inventory from regional distribution centers, data for salt sold or used by type may differ from totals shown in tables 1, 3, and 4, which are derived from plant reports at salt production locations. Data may differ from totals shown in table 6 because of changes in inventory and/or incomplete data reporting.

[4]Less than ½ unit.

[5]Includes exports.

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TABLE 6

DISTRIBUTION OF DOMESTIC AND IMPORTED EVAPORATED AND ROCK SALT IN THE UNITED STATES, BY DESTINATION[1, 2]

(Thousand metric tons)

	2004				2005			
	Evaporated				Evaporated			
Destination	Vacuum and open pans	Solar	Rock	Total	Vacuum and open pans	Solar	Rock	Total
Alabama	69	3	74 r	145 r	81	3	69	154
Alaska	3	5	-- r	8	5	3	--	9
Arizona	12 r	105 r	2 r	120 r	12	105	1	118
Arkansas	49	2	47 r	99 r	49	3	48	100
California	220 r	689 r	3	912 r	220	648	3	871
Colorado	12	84 r	169	265 r	12	83	166	261
Connecticut	15 r	123 r	182	320 r	15	112	198	325
Delaware	5 r	13 r	2	21 r	6	13	5	23
District of Columbia	1	27	(3)	28	1	35	5	41
Florida	88	215 r	6	309 r	84	253	5	341
Georgia	85	59 r	49 r	193 r	87	48	49	184
Hawaii	(3)	1	--	2 r	(3)	1	--	1
Idaho	20 r	110 r	2	132 r	21	100	1	122
Illinois	340 r	121 r	1,800 r	2,260 r	343	119	2,360	2,820
Indiana	261 r	128 r	862 r	1,250 r	263	122	922	1,310
Iowa	132 r	111 r	516 r	758 r	133	119	629	882
Kansas	87	62	724 r	873 r	86	66	296	448
Kentucky	60 r	5	674 r	740 r	60	6	675	741
Louisiana	61 r	2	591 r	654 r	51	3	342	396
Maine	15	15 r	177 r	206 r	15	15	252	282
Maryland	64	87 r	21	172 r	65	172	23	259
Massachusetts	31 r	253 r	272 r	555 r	34	79	331	444
Michigan	276 r	45 r	2,530 r	2,850 r	281	44	2,900	3,230
Minnesota	160 r	213 r	573 r	946 r	134	200	829	1,160
Mississippi	35 r	1	247 r	283 r	31	1	219	251
Missouri	144 r	60 r	564 r	768 r	148	63	367	578
Montana	1	34 r	1	36 r	1	42	0	43
Nebraska	60 r	44 r	177 r	282 r	60	46	172	277
Nevada	6 r	280 r	(3)	285 r	6	256	0	262
New Hampshire	16 r	82 r	94 r	191 r	16	101	187	304
New Jersey	115 r	68 r	78	261 r	118	124	78	320
New Mexico	18 r	70	2	89	18	70	0	88
New York	196 r	52 r	2,850 r	3,090 r	196	40	3,190	3,420
North Carolina	116 r	89 r	108 r	313 r	116	61	98	275
North Dakota	6 r	14 r	4	24 r	11	13	5	29
Ohio	419 r	48 r	2,730 r	3,200 r	446	49	3,280	3,780
Oklahoma	35 r	23	42 r	100 r	33	26	45	104
Oregon	17	103 r	(3) r	121 r	17	110	0	127
Pennsylvania	186 r	115 r	2,020 r	2,320 r	187	92	2,260	2,540
Rhode Island	4	174 r	2 r	181 r	5	675	1	681
South Carolina	36 r	9 r	8	53 r	31	6	3	40
South Dakota	19	52 r	33	105 r	19	50	47	117
Tennessee	116	7 r	535 r	658 r	127	8	464	598
Texas	231 r	161 r	162 r	555 r	234	165	150	548
Utah	13 r	346 r	136	495 r	13	286	112	411
Vermont	7	5	347 r	359 r	6	5	419	430
Virginia	69 r	109 r	69 r	247 r	69	147	112	327
Washington	28 r	126 r	8	161 r	27	128	13	168
West Virginia	12	5	176 r	193 r	13	7	187	207
Wisconsin	215 r	145 r	1,280 r	1,640 r	215	149	1,720	2,080

See footnotes at end of table.

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TABLE 6—Continued

DISTRIBUTION OF DOMESTIC AND IMPORTED EVAPORATED AND ROCK SALT IN THE UNITED STATES, BY DESTINATION[1, 2]

(Thousand metric tons)

	2004				2005			
	Evaporated				Evaporated			
Destination	Vacuum and open pans	Solar	Rock	Total	Vacuum and open pans	Solar	Rock	Total
Wyoming	(3)	20 r	2	22 r	(3)	20	2	22
Other[4]	110 r	22	438	571 r	100	101	399	600
Total[5]	4,300 r	4,740 r	21,400 r	30,400 r	4,320	5,190	23,600	33,200

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Each salt type includes domestic and imported quantities. Brine is excluded because brine is not shipped out of State.

[3]Less than ½ unit.

[4]Includes shipments to overseas areas administered by the United States, Puerto Rico, exports, and some shipments to unspecified destinations.

[5]Because data include salt imported, purchased, and/or sold from inventory from regional distribution centers, data for evaporated and rock salt distributed by State may differ from totals shown in tables 1 and 3, which are derived from plant reports at salt production locations. Data may differ from totals shown in table 5 because of changes in inventory and/or incomplete data reporting.

TABLE 7

AVERAGE VALUE OF SALT, BY PRODUCT FORM AND TYPE[1]

(Dollars per metric ton)

Product form	Vacuum and open pans	Solar	Rock	Brine
2004:				
Bulk	62.36	23.33	24.22	7.01
Compressed pellets	138.26	114.85	XX	XX
Packaged	147.13	67.59	85.55	XX
Average[2]	128.39	49.25	25.83	7.01
Pressed blocks	105.30	93.53	103.57	XX
2005:				
Bulk	71.23	27.30	24.73	7.03
Compressed pellets	143.77	125.14	XX	XX
Packaged	146.50	79.69	80.89	XX
Average[2]	130.75	58.14	25.84	7.03
Pressed blocks	109.71	102.91	111.08	XX

XX Not applicable.

[1]Net selling value, free on board plant, excluding container costs.

[2]Salt value data reported prior to 1984 were an aggregate value per metric ton of bulk, compressed pellets, and packaged salt. For time series continuity, an average of these three types of product forms is presented that is based on the aggregated values and quantities of the product form for each type of salt listed in table 3.

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TABLE 8
U.S. EXPORTS OF SALT, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

Country	2004		2005	
	Quantity	Value[2]	Quantity	Value[2]
Argentina	1	91	1	214
Bahamas, The	1	213	1	251
Bahrain	1	322	1	256
Belgium	2	289	2	284
Canada	971	31,100	686	32,700
Chile	1	216	(3)	86
China	4	204	9	395
Colombia	1	250	4	461
Costa Rica	2	183	3	355
Dominican Republic	(3)	124	(3)	135
El Salvador	1	172	1	219
Germany	1	1,140	20	1,000
Honduras	14	1,640	9	1,220
Hong Kong	1	276	1	310
Israel	(3)	29	(3)	41
Italy	(3)	31	(3)	252
Japan	2	2,130	22	2,860
Korea, Republic of	1	190	(3)	224
Kuwait	(3)	93	(3)	258
Lebanon	2	226	1	139
Malaysia	4	271	2	85
Mexico	74	3,620	92	4,270
Netherlands	2	344	1	153
Norway	1	93	1	307
Panama	1	116	1	115
Philippines	4	394	2	164
Saudi Arabia	10	916	6	1,480
United Arab Emirates	3	609	1	462
United Kingdom	4	839	3	731
Other	4	1,480	12	2,360
Total	1,110	47,600	879	51,800

[1]Data are rounded to no more than three significant digits; may not add to totals shown. (The Harmonized Tariff Schedule of the United States code for salt is 2501.00.0000.)

[2]Free alongside ship value at U.S. ports.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 9
U.S. EXPORTS OF SALT, BY CUSTOMS DISTRICT[1]

(Thousand metric tons and thousand dollars)

District	2004		2005	
	Quantity	Value[2]	Quantity	Value[2]
Anchorage, AK	3	156	1	260
Baltimore, MD	2	571	5	1,310
Buffalo, NY	61	3,020	34	3,100
Charleston, SC	(3)	23	(3)	11
Chicago, IL	1	1,180	20	2,400
Cleveland, OH	423	9,950	373	11,200
Dallas-Fort Worth, TX	(3)	36	(3)	61
Detroit, MI	237	7,660	60	5,290
Duluth, MN	14	278	(3)	47
El Paso, TX	17	941	5	291
Great Falls, MT	5	668	10	888
Honolulu, HI	(3)	13	(3)	44
Houston, TX	19	3,170	18	3,070
Laredo, TX	50	2,200	71	3,370
Los Angeles, CA	14	2,180	34	2,270
Miami, FL	2	528	6	1,410
Mobile, AL	7	599	2	182
New Orleans, LA	1	135	(3)	71
New York, NY	16	1,680	8	2,300
Nogales, AZ	3	109	2	78
Norfolk, VA	1	193	1	318
Ogdensburg, NY	13	1,450	51	2,750
Pembina, ND	3	410	3	597
Philadelphia, PA	(3)	414	1	124
Portland, ME	--	--	(3)	63
St. Albans, VT	(3)	16	(3)	33
San Diego, CA	5	387	14	546
San Francisco, CA	23	763	36	1,680
Savannah, GA	(3)	77	(3)	56
Seattle, WA	21	1,140	10	978
Tampa, FL	1	216	1	149
Other[4]	171	7,410	114	6,850
Total	1,110	47,600	879	51,800

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown. (The Harmonized Tariff Schedule of the United States code for salt is 2501.00.0000.)

[2]Free alongside ship value at U.S. ports.

[3]Less than ½ unit.

[4]Unknown but assumed to be rail and/or truck shipments to Canada through various points of departure.

Source: U.S. Census Bureau.

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TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF SALT, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

Country	2004		2005	
	Quantity	Value[2]	Quantity	Value[2]
Australia	(3)	34	1	112
Bahamas, The	1,110	11,600	1,370	14,200
Belgium	11	131	1	235
Brazil	93	1,840	150	2,220
Canada	4,240	62,900	3,950	62,600
Chile	3,370	31,200	3,840	49,700
China	4	1,260	12	2,010
Colombia	5	234	4	410
Egypt	414	3,340	588	5,820
France	10	3,780	30	4,960
Germany	6	1,350	4	1,200
India	38	438	(3)	9
Ireland	96	683	17	120
Israel	1	729	2	730
Italy	93	1,690	49	1,310
Japan	1	121	(3)	46
Korea, Republic of	3	676	1	761
Mexico	1,120	15,000	927	14,700
Netherlands	127	4,510	62	2,180
Netherlands Antilles	436	8,090	270	5,280
New Zealand	4	253	4	360
Pakistan	(3)	71	(3)	59
Panama	44	946	102	1,670
Peru	346	2,600	500	3,930
South Africa	3	197	6	461
Spain	1	585	3	1,480
United Kingdom	204	2,500	140	2,220
Venezuela	131	1,480	40	404
Other	1	627	6	871
Total	11,900	159,000	12,100	180,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown. (The Harmonized Tariff Schedule of the United States code for salt is 2501.00.0000.)

[2]Customs value only.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 11
U.S. IMPORTS OF SALT, BY CUSTOMS DISTRICT[1]

(Thousand metric tons and thousand dollars)

	2004		2005	
District	Quantity	Value[2]	Quantity	Value[2]
Anchorage, AK	2	252	23	722
Baltimore, MD	1,190	16,800	1,030	18,200
Boston, MA	986	11,100	1,290	16,100
Buffalo, NY	131	3,620	57	1,530
Charleston, SC	197	4,530	128	3,080
Charlotte, NC	--	--	73	2,020
Chicago, IL	896	11,800	525	7,580
Cleveland, OH	386	5,030	337	4,500
Columbia-Snake, OR	(3)	5	(3)	91
Dallas-Fort Worth, TX	(3)	18	(3)	32
Detroit, MI	1,160	20,500	1,510	25,000
Duluth, MN	189	2,710	67	869
El Paso, TX	--	--	(3)	2
Great Falls, MT	1	61	2	210
Honolulu, HI	(3)	20	(3)	3
Houston-Galveston, TX	1	759	4	925
Laredo, TX	1	373	1	289
Los Angeles, CA	72	2,300	121	3,620
Miami, FL	(3)	194	(3)	166
Milwaukee, WI	931	8,380	839	12,100
Minneapolis, MN	(3)	26	44	662
Mobile, AL	(3)	48	(3)	34
New Orleans, LA	146	1,880	19	654
New York, NY	2,680	30,300	2,480	34,900
Nogales, AZ	(3)	61	(3)	23
Norfolk, VA	163	1,570	112	1,500
Ogdensburg, NY	172	3,260	162	2,390
Pembina, ND	2	291	3	499
Philadelphia, PA	951	10,200	1,110	13,700
Portland, ME	613	6,390	1,060	12,400
Providence, RI	506	5,860	706	7,410
St. Albans, VT	13	974	2	309
St. Louis, MO	3	234	5	315
San Diego, CA	1	163	1	259
San Francisco, CA	1	396	4	729
San Juan, PR	6	263	4	425
Savannah, GA	40	1,000	42	1,590
Seattle, WA	15	774	2	603
Tampa, FL	354	5,380	309	4,710
Wilmington, NC	99	1,410	--	--
Total	11,900	159,000	12,100	180,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown. (The Harmonized Tariff Schedule of the United States code for salt is 2501.00.0000.)

[2]Customs value only.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 12

SALT: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	2001	2002	2003	2004[e]	2005[e]
Afghanistan, rock salt[e]	13	13	13	13	12
Albania	26	23	21 [r]	25 [r, 4]	20
Algeria, brine and sea salt	185	205	191	183	197
Angola[e]	30	30	30	30	30
Argentina	1,270	1,080	1,668 [r]	1,362 [r, 4]	1,400
Armenia	30 [e]	30	32	32	33
Australia, salt and marine salt	9,536	9,887	9,800 [e]	11,221 [4]	12,384 [4]
Austria:[e]					
Brine salt	400	400	400	400	400
Rock salt	1	1	1	1	1
Total	401	401	401	401	401
Azerbaijan	4 [e]	5	8	8	8
Bahamas, The	900 [e]	900 [e]	1,342 [r]	1,269 [r, 4]	1,270
Bangladesh, marine salt[e, 5]	350	350	350	350	350
Belarus[e]	300	300	300	300	300
Bolivia	(6)	4	2	1 [r, 4]	1
Bosnia and Herzegovina[e]	90 [r]	98 [r]	84 [r]	85 [r]	85
Botswana[7]	179	315	229	208 [4]	210
Brazil:					
Brine salt	4,370	4,835	5,144	5,206 [r, 4]	5,210 [p]
Rock salt	1,208	1,274	1,420 [r]	1,442 [r, 4]	1,450 [p]
Total	5,578	6,109	6,564 [r]	6,648 [r, 4]	6,660 [p]
Bulgaria	1,931	1,800 [e]	1,882	1,900 [r]	1,900
Burkina Faso[e]	5	5	5	5	5
Burma[e, 8]	35	35	35	35	35
Cambodia[e]	40	40	40	40	40
Canada	13,725	12,736	13,718 [r]	14,125 [4]	14,500 [4]
Cape Verde[e]	2	2	2	2	2
Chile	5,989	3,503	6,213	4,939 [r, 4]	4,940
China	34,105	36,024	32,424	37,101 [4]	44,547 [4]
Colombia:					
Marine salt	286 [r]	336	248	294 [r, 4]	300
Rock salt	110 [r]	192	199	232 [r, 4]	250
Total	396 [r]	527	447	526 [r, 4]	550
Costa Rica, marine salt[e]	37	37	37	37	37
Croatia	33	37	31	23 [r]	25
Cuba	180	180 [e]	180 [e]	188 [r]	190
Denmark, sales[e]	600	600	605	610	610
Djibouti	173	162	128	30	30
Dominican Republic:					
Marine salt[e]	50	50	50	50	50
Rock salt	190	157	107	-- [r]	--
Total	240	207	157	50 [r]	50
Ecuador[e]	90	90	90	90	90
Egypt[e]	2,400	2,400	2,400	2,400	2,400
El Salvador, marine salt	32	32	31	31	31
Eritirea, marine salt	78	116	5 [r]	3 [r, 4]	3
Ethiopia, rock salt[e, 5]	90 [r]	120 [r]	145 [r]	200 [r, 4]	200
France:[e]					
Brine salt	1,500	1,500	1,500	1,500	1,500
Marine salt	1,200	1,200	1,200	1,200	1,200
Rock salt	300	300	300	300	300
Salt in solution	4,000	4,000	4,000	4,000	4,000
Total	7,000	7,000	7,000	7,000	7,000

See footnotes at end of table.

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TABLE 12—Continued
SALT: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	2001	2002	2003	2004[e]	2005[e]
Georgia[e]	30	30	30	30	30
Germany:					
Industrial brines	7,629	8,307	9,078	10,432 [4]	10,400
Rock salt and other	5,887 [r]	6,468 [r]	6,495 [r]	7,692 [r, 4]	7,700
Salt, evaporated	827 [r]	858 [r]	727 [r]	572 [r, 4]	572
Total	14,343 [r]	15,632 [r]	16,300 [r]	18,696 [r, 4]	18,700
Ghana[e]	68	99	250	265 [r]	265
Greece[e]	150	150	150	150	150
Guadeloupe[e]	49	49	49	49	49
Guatemala[e]	50	50	60 [r]	60 [r]	60
Guinea[e]	15	15	15	15	15
Honduras[e]	25	25	26 [r]	26 [r]	26
Iceland[e]	5	5	5	5	5
India:[e]					
Marine salt	14,500	14,500	15,000	15,000	15,500
Rock salt	3	3	3	3	3
Total	14,500 [r]	14,500 [r]	15,000 [r]	15,000	15,500
Indonesia[e]	680	680	680	680	680
Iran[9]	1,559 [r]	1,664 [r]	2,003 [r]	1,791 [r, 4]	2,000
Iraq[e]	300	203 [4]	50	50	25
Israel	460 [r, e]	392 [r]	376 [r]	398 [r, 4]	400
Italy:[e]					
Brine and rock salt	3,000	3,000	3,000	3,000	3,000
Marine salt, crude[10]	600	600	600	600	600
Total	3,600	3,600	3,600	3,600	3,600
Jamaica[e]	19 [4]	19	19	19	19
Japan	1,358	1,282	1,263 [r]	1,273 [r, 4]	1,250
Jordan	329	407	12 [r]	29 [r, 4]	29
Kenya, crude salt	6	19	21 [r]	31 [r, 4]	32
Korea, North[e]	500	500	500	500	500
Korea, Republic of[e]	800	800	800	800	800
Kuwait[e]	43 [r]	45 [r]	45 [r]	50 [r]	50
Laos, rock salt	3	5	16	15	15
Lebanon[e]	4	4	4	4	4
Libya[e]	40	40	40	40	40
Madagascar[e]	26 [4]	17	26 [r]	26 [r]	26
Mali[e]	6	6	6	6	6
Malta, marine salt[e]	(6)	(6)	(6)	(6)	(6)
Martinique[e]	200	200	200	200	200
Mauritania[e]	6	6	(6) [r, 4]	(6) [r, 4]	(6)
Mauritius	7	7	7 [e]	8	8
Mexico	8,501	7,802	7,547	8,566 [r, 4]	9,242 [4]
Mongolia, mine output	2	1	2	2	2 [4]
Morocco, marine and rock salt	234	267 [r]	237 [r]	254 [r, 4]	254
Mozambique, marine salt[e]	10	80	80	80	80
Namibia, marine salt	543	630	698	754 [r]	700
Nepal[e, 11]	5	5	5	4	4
Netherlands[e]	5,000	5,000	5,000	5,000	5,000
Netherlands Antilles[e]	500	500	500	500	500
New Zealand[e]	70	70	70	70	70
Nicaragua, marine salt	18	30	31	31	31
Niger[e]	2	2	2	2	2
Oman	14	14	15 [e]	15	15

See footnotes at end of table.

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TABLE 12—Continued
SALT: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	2001	2002	2003	2004[e]	2005[e]
Pakistan:[e, 5]					
Marine salt	20	20	20	20	20
Rock salt	1,300	1,300	1,300	1,300	1,300
Total	1,320	1,320	1,320	1,320	1,320
Panama, marine salt[e]	23	23	23	23	23
Peru	419	279	187	249 [4]	250
Philippines, marine salt[e]	600	600	600	600	600
Poland:					
Rock salt	787	839	848	1,099 [r, 4]	1,100
Recovered from brine	2,689 [r]	2,719 [r]	3,812 [r]	4,043 [r, 4]	3,900
Total	3,476 [r]	3,558 [r]	4,660 [r]	5,142 [r, 4]	5,000
Portugal, rock salt[e]	600	600	600	600	600
Romania:					
Rock salt	48	46 [e]	47	43 [r]	45
Other	2,224 [r]	2,257 [r]	2,417 [r]	2,398 [r, 4]	2,400
Total	2,272 [r]	2,303 [r]	2,464 [r]	2,441 [r, 4]	2,450
Russia[e]	2,800 [4]	2,800	2,800	2,800	2,800
Saudi Arabia[e]	200 [4]	220 [r]	220 [r]	230 [r]	230
Senegal[e]	110 [4]	1,720 [r]	235 [r]	240 [r]	240
Serbia and Montenegro	62	42	78 [r]	75 [r]	75
Slovakia[e]	123	97	95	95 [r]	95
Slovenia[e]	108	128	125	125	125
Somalia[e]	1	1	1	1	1
South Africa	354 [r]	429 [r]	441 [r]	395 [r, 4]	383 [p]
Spain:[e]					
Marine and other evaporated salt	1,200	1,200	1,200	1,200	1,200
Rock salt	2,000	2,000	2,000	2,000	2,000
Total	3,200	3,200	3,200	3,200	3,200
Sri Lanka	130	73	79	79	80
Sudan	78	83	61 [r]	62 [r]	62
Switzerland[e]	300	300	300	300	300
Syria	190	146	146 [e]	146	146
Taiwan, marine salt	66	57	(6)	-- [4]	--
Tanzania	65	71	59	57 [r, 4]	58
Thailand:					
Rock salt	853	909	892	1,031 [r, 4]	1,000
Other[e]	100	100	100	100	100
Total	953	1,009	992	1,131 [r, 4]	1,100
Tunisia, marine salt	654	616	700 [e]	608 [4]	600
Turkey	1,771	2,197	2,243	2,158 [r, 4]	2,200
Turkmenistan[e]	215	215	215	215	215
Uganda[e]	5	5	5	5	5
Ukraine[e]	2,300	2,300	2,300	2,300	2,300
United Kingdom:[e]					
Brine salt[12]	1,300	1,300	1,300	1,300	1,300
Rock salt	1,500	1,500	1,500	1,500	1,500
Other salt[12]	3,000	3,000	3,000	3,000	3,000
Total	5,800	5,800	5,800	5,800	5,800
United States, including Puerto Rico:					
United States:					
Brine	20,400	19,300	20,000	20,500 [4]	19,900 [4]
Rock salt	17,000	13,500	16,300	18,300 [4]	17,700 [4]
Solar salt	3,310	3,390	3,330	3,520 [4]	3,430 [4]
Vacuum and open pan	4,120	4,100	4,070	4,100 [4]	4,170 [4]

See footnotes at end of table.

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TABLE 12—Continued
SALT: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	2001	2002	2003	2004[e]	2005[e]
United States, including Puerto Rico—Continued:					
Puerto Rico[e]	45	45	45	45	45
Total	44,800	40,300	43,700	46,500 [4]	45,200 [4]
Venezuela[e]	350	350	350	350	350
Vietnam	669	1,089	1,275	1,300	1,400
Yemen[e]	95	125	116	120	120
Grand total	214,000 [r]	212,000 [r]	218,000 [r]	229,000 [r]	238,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 5, 2006.

[3]Salt is produced in many other countries, but quantities are relatively insignificant and reliable production data are not available. Some salt brine production data for manufacture of chlorine, caustic soda, and soda ash are not reported because of incomplete data reporting by many countries.

[4]Reported figure.

[5]Year ending June 30 of that stated.

[6]Less than ½ unit.

[7]From natural soda ash production.

[8]Brine salt produced, as reported by the Government of Burma in metric tons, was as follows: 2001—61,466; 2002—59,825; 2003—73,112; 2004—58,395 (revised); and 2005—58,000 estimated.

[9]Year beginning March 21 of that stated.

[10]Does not include production from Sardinia and Sicily, which is estimated to be 200,000 metric tons per year.

[11]Year ending July 15 of that stated.

[12]Data captioned "Brine salt" for the United Kingdom are the quantities of salt obtained from the evaporation of brine; that captioned "Other salt" are for salt content of brines used for purposes other than production of salt.

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SAND AND GRAVEL, CONSTRUCTION

By Wallace P. Bolen

Domestic survey data and tables were prepared by Cheryl J. Crawford, Brian W. Jaskula, Joseph M. Krisanda, and Hoa P. Phamdang, statistical assistants.

Construction sand and gravel is one of the most accessible and widely used natural resources. The construction sand and gravel industry is a major contributor to the economic well-being of the Nation and produces a large volume of mineral products with a low-unit value. Sand and gravel and crushed stone combined are defined as construction aggregate. The crushed stone industry is reviewed in a separate chapter of the U.S. Geological Survey (USGS) Minerals Yearbook; both of these mineral commodities are usually included in reviews of national, State, or local aggregates industries.

A total of 1.27 billion metric tons (Gt) of construction sand and gravel was produced in the United States in 2005. This record-high production was an increase of about 33 million metric tons (Mt), or 2.7%, compared with that of 2004. After a decrease in production in 1991, sand and gravel production increased each year for the following 14 years. All percentages in this report were computed using unrounded data. Total construction activity in the United States increased by 10% in 2005, following gains of 10% in 2004 and 3% in 2003. According to the U.S. Census Bureau, construction gains were recorded in most categories with residential building gaining 14%, nonbuilding construction gaining 7%, and nonresidential building gaining 5%. Single-family home sales set another record as they topped 2004 sales by 6.6% (Rock Products, 2006).

Each year, hundreds of sand and gravel operations are idled, closed, or abandoned, and hundreds more are reactivated or opened. The changing location of construction and highway projects is the major stimulus in decisions to open, idle, or close operations.

In 2005, 6,029 construction sand and gravel operations were active, 581 operations were idle, and 189 operations either were reported to be closed or were assumed to be permanently shut down. Of the 6,029 active operations, 64 were classified as sales or distribution yards only; a sales yard is defined as a fixed location that receives sand and gravel from a distant source and sells it at the yard. In addition, 53 operations reported that they were either an open pit or a dredge combined with a sales yard that supplemented local production with material from a remote location. A small number of the idle sand and gravel operations reported recycling of asphalt and portland cement concrete, but no sand and gravel mining. In 2005, of the 6,029 active operations surveyed, 3,479, or 57.7%, responded to the USGS canvass. Their total production represented 68.3% of the 1.27 Gt produced in 2005. The 6,029 operations with 9,975 active sand and gravel pits were owned by 3,794 companies or government agencies operating in all 50 States. A review of the data provided by the U.S. Mine Safety and Health Administration for 2005 revealed 147 previously unaccounted for sand and gravel locations that reported at least 2,000 man-hours of activity within the year. Information was gathered from these "new" operations and they were included in this report.

Foreign trade of construction sand and gravel remained minor in 2005 but imports did reach record levels. According to the U.S. Census Bureau, exports decreased by 23% to 519,000 metric tons (t), and the value decreased by 12% to $28.2 million compared with the 2004 results (tables 1, 16). Imports increased by about 50% to 7.16 Mt, and the value increased by about 53% to $86.8 million (tables 1, 17). Imports are becoming a significant source for sand and gravel in some areas of the country.

Domestic apparent consumption of construction sand and gravel, which is defined as production for consumption (sold or used) plus total imports minus total exports, was 1.28 Gt. Though only by a very slight margin, this is the first time that imports have been significant enough to cause apparent consumption to be different from U.S. production. Imports and exports have historically been so minor as to not affect domestic apparent consumption.

Production

Of the four major geographic regions, the West again led the Nation in the production of construction sand and gravel with 521 Mt, or 41% of the U.S. total (table 2). It was followed by the Midwest with 360 Mt, or 28%; the South with 271 Mt, or 21%; and the Northeast with 122 Mt, or 10%. Compared with 2004, production in 2005 decreased in the Midwest and Northeast regions but increased in the South and West regions.

Of the nine geographic divisions, the Mountain led the Nation in the production of construction sand and gravel with 278 Mt, or 21.8% of the U.S. total, and was followed by the Pacific with 242 Mt, or 19.0%, and the East North Central with 225 Mt, or 17.7% (table 2; figure 1). Production increased in six of the nine divisions compared with that of 2004—South Atlantic, 11.3%; Mountain, 9.7%; New England, 4.3%; East South Central, 2.6%; Pacific, 1.4%; and West South Central, 0.8%. Production decreased in the three remaining divisions—Middle Atlantic, 5.0%; East North Central, 2.2%; and West North Central, 0.2%.

A review of the production of construction sand and gravel for consumption by size of operation indicates that about 34% of the total production came from 259 operations that reported 1 million metric tons per year (Mt/yr) production or more, 33% came from 2,001 operations that reported between 100,000 and 499,999 metric tons per year (t/yr), and 25% of the construction sand and gravel produced in 2005 came from 2,068 operations that reported between 500,000 and 999,999 t/yr. The largest number of operations (3,270, or 54% of total operations) produced less than 100,000 t/yr (9% of the total production) (table 8A).

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The estimated production for consumption by quarter for 2005 indicates that 31% of the construction sand and gravel in the United States was produced in the third quarter followed by the second and the fourth quarters (table 3). Estimated production data for each quarter also were available for most States (table 4).

In 2005, construction sand and gravel was produced in every State (tables 4-5). The leading States were, in descending order of tonnage, California, Arizona, Texas, Michigan, Minnesota, Nevada, Ohio, Washington, Colorado, and Wisconsin. The combined production of these 10 States represented about 54% of the national total. Production increased in 29 States and decreased in 21 States compared with that of 2004. Production increases of greater than 10% were reported in 13 States—Florida (27.7%), Georgia (20.2%), Nevada (17.0%), New Mexico (16.4%), Iowa (15.9%), Massachusetts (14.0%), Arkansas (13.7%), Washington (13.6%), Utah (13.0%), South Carolina (11.8%), Oklahoma (11.4%), Wyoming (11.2%), and Hawaii (11.0%). Production decreases of greater than 10% were recorded in only 3 States—West Virginia (39.3%), Pennsylvania (14.7%), and Delaware (11.5%).

In 2005, the leading domestic commercial producers of construction sand and gravel were, in descending order of production, Oldcastle, Inc./Materials Group; Hanson Building Materials America, Inc.; Rinker Materials Corp.; Vulcan Materials Co.; MDU Resources Group, Inc./Knife River Corporation; CEMEX, Inc.; Aggregates Industries, Inc.; Martin Marietta Aggregates; Lafarge North America, Inc.; and Granite Construction Company.

Some information about the production of construction sand and gravel in foreign countries can be found in the USGS Minerals Yearbook, volume III, Area Reports: International. For nonreporting countries, estimates of sand and gravel and crushed stone production can be based on indirect indicators, such as the levels of cement and asphalt consumption.

Mergers and acquisitions in the construction sand and gravel industry proceeded at increased levels in 2005. Several large acquisitions were recorded in 2005 while in 2004 activity consisted of small or medium-sized companies being snapped up by larger companies. Some of the more significant changes in ownership in the sand and gravel industry in 2005 are listed below.

In February, CEMEX S.A de C.V., a Mexico-based global producer of aggregates and cement finalized the acquisition of RMC Group plc, a British conglomerate that was a significant global producer of ready-mix concrete and aggregates. In 2004, RMC was the 12th leading producer of sand and gravel in the United States. With this acquisition, CEMEX became the sixth leading producer of sand and gravel in 2005 after being the seventh leading producer in 2004 (Aggregates Manager, 2005a).

In March, the Swiss-based Holcim Group Ltd. acquired the United Kingdom-based Aggregates Industries plc, the seventh leading producer of sand and gravel in the United States in 2005. Holcim was the second leading producer of cement in the world and this $3.4 billion purchase gives Holcim control of about 75 sand and gravel operations in 12 States (Aggregates Manager, 2005b).

Also in March, Vulcan Materials Co. purchased New West Materials Co., LLC of Phoenix and Tucson, AZ. New West produced from four operations and was the fifth leading producer in Arizona in 2004. Vulcan is now the third leading producer in Arizona and was the eighth leading producer in the State in 2004 (Aggregates Manager, 2005f). In August, Vulcan purchased Crister Companies, Inc. in Indiana. Vulcan moved up to the eighth leading producer of sand and gravel in the State in 2005 with this addition and remained the fourth leading producer in the United States (Aggregates Manager, 2005e).

In April, Rinker Materials Corp. purchased Pahrump Concrete, a concrete and sand and gravel operation about 97 kilometers west of Las Vegas, NV. Rinker is the third leading producer of sand and gravel in the United States and now has two operations in Nevada and about 60 operations in 9 States (Rock Products, 2005).

In June, MDU Resources Group, through its Knife River Corp. subsidiary, purchased seven construction materials operations in Oregon. MDU is the fifth leading producer of sand and gravel in the United States. MDU is by far the leading producer in Oregon and these additional operations helped the gap widen in 2005 (Aggregates Manager, 2005c).

Also in June, Hanson PLC announced the acquisition of Mission Valley Rock Company, Sunol, CA. Mission Valley was a major producer of sand and gravel in the Nation's leading State for sand and gravel production. Even with this acquisition, Hanson declined from the fourth leading producer in 2004 to the fifth leading in 2005 in California. However, Hanson maintained its position as the second leading producer of sand and gravel in the Nation (Aggregates Manager, 2005d).

Oldcastle Materials, Inc., the leading producer of sand and gravel in the United States was also active in 2005, especially in October and November. The company made acquisitions in Idaho, Iowa, Minnesota, and Utah. Oldcastle was already the leading producer in all these States, except Minnesota, where they had no presence until November when they purchased Southern Minnesota Construction. Southern Minnesota Construction was the leading aggregates and asphalt supplier in the south-central region of Minnesota with 80 Mt of aggregate reserves and a production of about 3 million metric tons per year of aggregate (Aggregates Manager, 2006b).

In November, Lafarge North America, Inc. acquired Wichita, KS-based Ritchie Corp., a supplier of ready-mix and aggregates. Ritchie was the leading producer of construction sand and gravel in Kansas and this purchase represents a significant first move for Lafarge. Prior to this, Lafarge did not have any sand and gravel presence in Kansas and now they are the number one producer in the State. Lafarge remains the ninth leading domestic producer of sand and gravel (Aggregates Manager, 2006b).

Production of construction sand and gravel reported by producers to the USGS was material that was sold or used by the companies. Stockpiled production is not reported until it is sold or consumed by the producer. Because no consumption surveys are conducted by the USGS for sand and gravel, the sold or used tonnage is assumed to represent the amount produced for domestic consumption and export. Because some of the construction sand and gravel producers did not report a breakdown by end use, their total production was reported under "Unspecified uses, reported." The estimated production

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of nonrespondents was reported under "Unspecified uses, estimated."

Of the 1.27 Gt of construction sand and gravel produced in 2005, 48.8% was for unspecified uses (table 6). Of the remaining 651 Mt, 45.1% was used as concrete aggregate; 21.5%, for road base and coverings and road stabilization; 14.1%, for construction fill; 12.0%, for asphaltic concrete aggregate and other bituminous mixtures; 2.1%, for plaster and gunite sands; 0.8%, for concrete products, such as blocks, bricks, and pipes; and the remainder for filtration, railroad ballast, roofing granules, snow and ice control, and other miscellaneous uses.

To provide a more accurate estimate of the consumption patterns for construction sand and gravel, the unspecified uses are not included in the above percentages. In any marketing or use-pattern analysis, the total quantities included in "Unspecified uses" may be distributed among the reported use categories by applying the above percentages. Compared with 2004, about 4.1% more of the sand and gravel production was reported for specific uses, and this must be taken into account when analyzing changes in market consumption in light of the total increase in U.S. production of 2.7%.

Additional information regarding production and/or consumption of construction sand and gravel by major uses in each State and State district can be found in the USGS Minerals Yearbook, volume II, Area Reports: Domestic.

Recycling

The aggregates industry has been involved with recycling for several decades. Recycling has become more important to aggregates producers, and the number of aggregates-producing companies that are recycling has generally been increasing. Recycling in this industry generally refers to the crushing, screening, and reuse of asphalt and cement concretes. Aggregates companies and related asphalt and ready-mix companies are often involved in construction projects during which they collect and reuse the materials at the site. Sometimes construction companies haul their materials to a recycling location where the asphalt or concrete is processed for reuse. The annual survey of construction sand and gravel producers collects information only on recycling of asphalt and cement concrete by sand-and-gravel-producing companies. These amounts represent a small percentage of the total recycled cement and asphalt concretes because the recycling of these materials is done mostly by the construction or demolition companies, and those companies are not surveyed by the USGS.

Asphalt Concrete.—In 2005, 3.75 Mt of asphalt concrete valued at $23.7 million was recycled by 171 sand and gravel companies in 35 States; this quantity represented an 11.0% decrease compared with that of 2004 (tables 12-13). The leading States were, in descending order of tonnage recycled, California, Minnesota, and Utah. The leading companies were, in descending order of tonnage produced, Granite Construction; The Lane Construction Co.; Midwest Asphalt Corp.; Troesh Recycling, Inc.; and Vulcan Materials.

Cement Concrete.—In 2005, about 4.6 Mt of cement concrete valued at $27 million was recycled by 166 companies in 35 States; this tonnage represented a 13% increase compared with that of 2004 (tables 14-15). The leading States were, in descending order of tonnage recycled, California, Minnesota, and Michigan. The leading companies were, in descending order of quantity produced, Vulcan Materials; Kalin Construction Co.; Danner, Inc.; Custom Crushing and Recycling Co.; and Midwest Asphalt Corp.

Transportation

Information regarding the method of transportation of construction sand and gravel from the pit or processing plant to the first point of sale or use is available for each geographic division and the total United States. Reports regarding the method of transportation were provided by the producers for 610 Mt, or 48% of the total U.S. production of construction sand and gravel. Of this total, 81.6% was transported by truck; 2.8%, by waterway; and 2.0%, by rail (table 9). A significant amount of construction sand and gravel produced (about 13.2%) was not transported and was used at or near the production site, probably for cement concrete or asphalt production. Because most producers neither keep records of nor report shipping distances or cost per metric ton per mile, transportation cost data are not available.

Prices

Prices in this chapter are free on board (f.o.b.) plant, usually the first point of sale or captive use. This value does not include transportation from the plant or yard to the consumer. It does include all costs of mining, processing, in-plant transportation, overhead, and profit.

The 2005 average unit price increased by about 10.2% to $5.86 per metric ton compared with that of 2004 (table 6). By use, the unit prices varied from a high of $10.36 per ton for railroad ballast to a low of $3.94 per ton for fill. The largest increases were recorded for road base and coverings (33.3%), railroad ballast (29.2%), and concrete products (26.0%). The largest decreases were for lime type road stabilization (7.4%), and roofing granules (1.9%). The U.S. Bureau of Labor Statistics (BLS) reported by regions in the United States that construction sand prices increased between 1.8% and 13.7% from 2004 to 2005. For construction gravel, the BLS reported increases between 4.5% and 13.5% for the same period (Aggregates Manager, 2006a).

Foreign Trade

The widespread distribution of domestic sand and gravel deposits and the high cost of transportation limit foreign trade to mostly local transactions across international boundaries. U.S. imports and exports represented less than 1% of domestic consumption.

According to the U.S. Census Bureau, exports of construction sand increased by about 10.5% to 137,000 t compared with that of 2004, but the value decreased by about 15.1% to $23.4 million (table 16). Canada, which was the leading destination, received about 47% of the total sand, followed by Taiwan with 25% and Mexico with 7%. Exports of construction gravel

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decreased by nearly 31% to 382,000 t compared with those of 2004, but the value increased by about 4.1% to $4.8 million. Canada, which was the leading destination, received about 89.8% of the total gravel. The average value of the sand and gravel exports in 2005 was $54.27 per ton; this was up from $47.45 per ton in 2004. These high values may be owing to some higher grade sand and gravel being misclassified as construction sand and gravel.

Imports increased by about 50% to 7.16 Mt, and the value increased by about 53% to $86.8 million (table 17). Canada was the leading source of imported construction sand and gravel with 60.2% of the total. Mexico supplied about 34.3% of the imports. The average value of the sand and gravel imports was $12.12 per ton, up from $11.95 per ton in 2004.

Outlook

The demand for construction sand and gravel in 2006 is expected to increase between 1% and 3% compared with that of 2005. Data from the USGS quarterly survey of aggregates producers indicate about a 2% increase in sales of sand and gravel compared with those of the first half of 2005. Most regions of the United States also will probably have increased sales in the second half of 2006, and demand will likely rise compared with 2005 levels particularly if oil prices remain below the higher prices experienced in the first half of 2006. Lower fuel prices should help to keep the cost of asphalt and cement down and increase consumption of downstream aggregate-containing products: asphalt and portland cement concrete. Lower oil prices would also make aggregates more affordable (by decreasing production cost), and therefore, limited public dollars for road and highway construction could be spent on more projects and aggregate consumption would increase. Nonresidential construction has been strong in 2006 and could also help to increase demand for aggregates. This more positive scenario will be tempered, however, owing to a marked drop in residential construction and home sales in 2006.

After increases of about 10% as recorded in 2005, construction sand and gravel f.o.b. prices are expected to increase by only about 4% to 6% for the full 12 months of 2006, partially owing to the rising cost of fuel used in the mining processes. The rise in fuel cost, especially in the first part of 2006, is also expected to affect the delivered prices of construction sand and gravel. These price increases are expected to be more noticeable in and near metropolitan areas because, as nearby resources are used up, more aggregates will be transported from distant sources.

For 2006, the construction sand and gravel industry is expected to continue to consolidate. Resistance to mining, especially at the local level, will push production to more rural areas and increase transportation costs. The cost to acquire existing companies will increase because of the difficulty of starting a new "greenfield" operation. The length of time that is needed to put a new operation into production has been estimated to be from 5 to 10 years. This includes the time required to develop reserves, to acquire zoning and permit approvals, and to deliver and install the necessary production equipment. Also, throughout the process, the possibility exists that the project may have to be abandoned owing to local opposition and permit or zoning denial. Many companies prefer to buy permitted, active operations with reserves rather than face the cost and uncertainties involved with a greenfield operation.

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TABLE 1
SALIENT U.S. CONSTRUCTION SAND AND GRAVEL STATISTICS[1]

(Thousand metric tons and thousand dollars)

	2001	2002	2003	2004	2005
Sold or used by producers:[2]					
Quantity	1,130,000	1,130,000	1,160,000	1,240,000	1,270,000
Value	5,670,000	5,750,000	5,990,000	6,600,000 r	7,460,000
Exports, value	19,100	23,400	24,900	32,100	28,200
Imports, value	40,800	53,900	57,700	56,900	86,800

rRevised.
[1]Data are rounded to no more than three significant digits.
[2]Puerto Rico is excluded from all sand and gravel statistics.

TABLE 2
CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY GEOGRAPHIC DIVISION[1]

	2004				2005			
Region/division	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total
Northeast:								
New England	50,000	4.0	$287,000	4.4	52,100	4.1	$341,000	4.6
Middle Atlantic	73,100 r	5.9	435,000 r	6.6	69,500	5.5	460,000	6.2
Midwest:								
East North Central	231,000	18.6	1,020,000	15.4	225,000	17.7	1,070,000	14.3
West North Central	135,000	10.9	540,000	8.2	135,000	10.5	585,000	7.8
South:								
South Atlantic	89,000	7.2	456,000	6.9	99,000	7.9	584,000	7.9
East South Central	47,000 r	3.8	243,000	3.7	48,200	3.8	262,000	3.5
West South Central	122,000	9.8	646,000	9.8	123,000	9.7	712,000	9.5
West:								
Mountain	254,000 r	20.5 r	1,270,000	19.3	278,000	21.8	1,520,000	20.3
Pacific	239,000	19.3	1,700,000	25.8	242,000	19.0	1,940,000	25.9
Total	1,240,000	100.0	6,600,000 r	100.0	1,270,000	100.0	7,460,000	100.0

rRevised.
[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.

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TABLE 3

SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY QUARTER AND GEOGRAPHIC DIVISION[1]

Region/division	Quantity, 1st quarter (thousand metric tons)	Percentage change[2]	Quantity, 2d quarter (thousand metric tons)	Percentage change[2]	Quantity, 3d quarter (thousand metric tons)	Percentage change[2]	Quantity, 4th quarter (thousand metric tons)	Percentage change[2]	Total[3] Quantity (thousand metric tons)	Total[3] Value (thousands)
Northeast:										
New England	4,290	-4.8	12,900	-9.8	18,300	11.3	13,100	-11.5	48,500	$274,000
Middle Atlantic	8,240	-17.0	21,500	5.0	24,700	0.2	16,800	-8.0	71,200	444,000
Midwest:										
East North Central	25,500	-2.0	68,800	0.4	75,400	-4.5	54,500	-4.8	224,000	1,040,000
West North Central	10,300	18.9	40,300	4.3	64,700	15.6	32,500	2.2	148,000	578,000
South:										
South Atlantic	21,100	3.5	24,900	5.2	24,700	9.8	22,300	-0.9	92,900	490,000
East South Central	9,450	-1.0	11,500	-13.1	13,100	-2.1	10,600	-1.6	44,600	241,000
West South Central	31,300	13.3	34,200	4.7	32,800	-2.1	29,900	5.0	128,000	709,000
West:										
Mountain	49,300	6.4	74,900	-0.5	74,900	6.1	64,300	8.9	263,000	1,390,000
Pacific[4]	39,300	-13.3	56,000	-9.3	64,100	-4.1	58,200	6.9	218,000	1,640,000
Total[3]	210,000	-0.1	343,000	-1.7	387,000	2.3	307,000	3.0	1,250,000 [5]	6,800,000 [5]

[1]As published in the "Crushed Stone and Sand and Gravel in the Fourth Quarter of 2005" Mineral Industry Surveys.

[2]All percentage changes are calculated using unrounded totals. Percentage changes are based on the corresponding quarter of the previous year.

[3]Data may not add to totals shown because of independent rounding and differences between projected totals by States and regions.

[4]Does not include Alaska and Hawaii.

[5]Includes Alaska and Hawaii.

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TABLE 4

SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY QUARTER AND STATE[1]

State	Quantity 1st quarter (thousand metric tons)	Percentage change[2]	Quantity 2d quarter (thousand metric tons)	Percentage change[2]	Quantity 3d quarter (thousand metric tons)	Percentage change[2]	Quantity 4th quarter (thousand metric tons)	Percentage change[2]	Total[3] Quantity (thousand metric tons)	Total[3] Value (thousands)
Alabama	3,130	-10.9	3,390	-30.1	2,960	-14.4	2,480	-13.6	12,000	$55,800
Alaska	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Arizona	17,800	-0.6	24,500	5.3	22,100	7.9	22,300	23.4	86,600	491,000
Arkansas	2,340	24.2	2,750	-1.1	2,740	4.5	2,580	23.7	10,400	62,300
California	26,900	-23.1	40,300	-11.6	45,600	-4.0	40,800	8.1	154,000	1,250,000
Colorado	7,310	18.5	12,600	-11.1	12,700	17.1	9,740	0.4	42,300	256,000
Connecticut	718	4.6	2,490	8.7	3,160	10.4	2,360	-5.1	8,730	61,100
Delaware	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	2,040	15,700
Florida	7,940	8.5	8,360	8.9	7,790	10.3	7,390	2.0	31,500	165,000
Georgia	2,600	-0.3	3,070	57.5	3,330	63.4	2,930	9.3	11,900	53,300
Hawaii	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Idaho	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	18,900	75,400
Illinois	3,790	0.0	11,300	2.1	12,500	-10.4	9,460	-4.7	37,000	204,000
Indiana	3,630	-7.2	8,750	-1.4	8,650	-3.3	6,800	3.1	27,800	120,000
Iowa	1,870	44.2	5,820	14.0	9,140	51.5	5,730	22.1	22,600	103,000
Kansas	1,490	-21.6	2,680	-10.2	2,780	-0.8	2,240	-0.1	9,190	31,900
Kentucky	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	10,300	51,900
Louisiana	4,370	1.7	4,970	-2.5	5,100	-6.7	4,410	-2.1	18,800	105,000
Maine	373	-4.9	2,200	-38.2	4,360	15.4	2,760	-11.1	9,700	46,000
Maryland	2,310	-6.9	3,370	-2.4	3,530	3.0	3,130	-5.6	12,300	77,200
Massachusetts	1,890	-9.2	3,640	4.0	4,520	-6.2	4,000	-0.7	14,100	92,000
Michigan	4,960	-5.9	21,400	0.7	24,100	-5.1	16,200	-8.1	66,600	256,000
Minnesota	1,870	37.9	15,300	-0.7	29,200	11.9	11,500	-4.6	57,900	260,000
Mississippi	2,890	5.5	3,490	-8.8	4,300	5.2	3,590	4.3	14,300	85,800
Missouri	1,950	16.3	3,710	2.3	3,980	-4.0	2,980	7.4	12,600	65,100
Montana	1,120	-25.5	3,690	-25.6	5,040	9.1	2,850	-13.0	12,700	74,300
Nebraska	1,850	-5.2	5,260	20.2	5,440	16.6	3,860	-6.0	16,400	60,600
Nevada	8,850	-1.9	11,300	12.3	13,800	1.2	11,200	7.5	45,100	216,000
New Hampshire	859	-7.0	2,430	-8.4	3,150	15.9	2,470	-6.5	8,910	48,700
New Jersey	2,560	-38.0	5,210	4.7	4,920	2.4	6,140	-0.8	18,800	118,000
New Mexico	3,230	37.8	3,910	-0.4	3,830	-6.4	3,250	-1.0	14,200	97,900
New York	3,650	2.3	9,530	1.7	12,800	0.1	6,610	-10.8	32,600	196,000
North Carolina	2,520	2.2	3,040	-5.8	2,970	5.0	2,380	-18.9	10,900	59,700
North Dakota	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Ohio	6,290	-4.3	14,600	-0.8	16,300	-3.4	11,800	-6.8	49,000	267,000
Oklahoma	3,410	40.6	3,740	21.8	3,400	-6.9	3,020	7.4	13,600	64,000
Oregon	4,200	33.3	5,340	-1.2	7,120	1.9	6,550	20.0	23,200	145,000
Pennsylvania	2,050	-17.6	6,770	11.8	6,470	-1.3	4,360	-11.6	19,700	130,000
Rhode Island	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
South Carolina	2,350	5.9	2,730	4.4	3,020	15.8	2,600	3.4	10,700	39,600
South Dakota	922	5.0	4,400	30.5	6,220	6.2	3,310	-15.0	14,900	57,500
Tennessee	1,480	2.2	1,870	-8.1	2,380	-6.3	1,690	-6.8	7,420	47,200
Texas	21,300	10.2	22,700	4.9	21,400	-0.6	19,800	3.4	85,200	478,000
Utah	5,240	34.8	9,280	2.0	9,300	-2.8	6,930	-4.8	30,700	135,000
Vermont	332	-8.1	1,200	-15.8	2,460	58.1	1,090	-33.3	5,070	25,700
Virginia	2,620	-2.0	3,480	-5.3	3,410	2.6	3,040	-3.1	12,500	78,000
Washington	8,890	36.7	10,400	0.2	11,700	-8.4	11,300	-5.1	42,300	242,000
West Virginia	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	279	1,400
Wisconsin	5,310	18.9	13,900	4.0	15,000	0.8	10,400	-2.3	44,600	192,000
Wyoming	936	-24.9	2,760	-3.8	4,110	6.7	2,470	13.2	10,300	42,600
Total	XX	XX	XX	XX	XX	XX	XX	XX	1,250,000	6,800,000

XX Not applicable.

[1]As published in the "Crushed Stone and Sand and Gravel in the Fourth Quarter of 2005" Mineral Industry Surveys.

[2]All percentage changes are calculated using unrounded totals. Percentage changes are based on the corresponding quarter of the previous year.

[3]Data may not add to totals shown because of independent rounding and differences between projected totals by States and regions.

[4]State not included in quarterly survey.

[5]Owing to a low number of reporting companies, no production estimates by quarters were generated.

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TABLE 5
CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

State	2004 Quantity (thousand metric tons)	2004 Value (thousands)	2004 Unit value	2005 Quantity (thousand metric tons)	2005 Value (thousands)	2005 Unit value
Alabama	14,700 r	$65,400 r	$4.45	15,700	$70,500	$4.48
Alaska	9,470 r	51,700 r	5.48	8,660	48,100	5.56
Arizona	79,500 r	430,000	5.41 r	84,900	516,000	6.08
Arkansas	9,320 r	53,400 r	5.73 r	10,600	62,000	5.85
California	166,000	1,280,000	7.74	163,000	1,440,000	8.84
Colorado	41,100	235,000	5.72	44,700	280,000	6.26
Connecticut	8,330	55,600	6.67	8,400	64,200	7.64
Delaware	2,980	21,900	7.35	2,640	20,000	7.59
Florida	29,300	146,000	4.99	37,500	210,000	5.60
Georgia	9,270	39,400	4.26	11,100	68,300	6.14
Hawaii	1,260	12,100	9.65	1,390	17,500	12.54
Idaho	19,800 r	74,600 r	3.77	20,800	93,800	4.52
Illinois	38,700	203,000	5.25	37,400	210,000	5.60
Indiana	28,300	116,000	4.11	28,400	135,000	4.76
Iowa	17,100	74,300	4.33	19,900	93,100	4.69
Kansas	9,950 r	32,800	3.30 r	10,100	36,900	3.66
Kentucky	10,300	49,700	4.82	10,500	55,000	5.25
Louisiana	19,400	103,000	5.30	18,600	113,000	6.07
Maine	10,800	48,900 r	4.52	11,100	57,400	5.16
Maryland	12,700	75,500	5.96	12,300	89,500	7.25
Massachusetts	14,400	89,900	6.23	16,500	117,000	7.12
Michigan	69,400 r	254,000	3.66	64,800	243,000	3.75
Minnesota	54,800 r	235,000	4.29	54,100	253,000	4.68
Mississippi	14,100 r	80,800 r	5.73	14,400	85,200	5.93
Missouri	12,200	60,100	4.91	12,200	61,600	5.06
Montana	14,300 r	79,600 r	5.58	14,000	83,600	5.97
Nebraska	15,100	53,200	3.52	14,300	60,200	4.22
Nevada	44,700 r	199,000 r	4.46 r	52,300	230,000	4.41
New Hampshire	8,940	46,600	5.21	8,400	47,400	5.64
New Jersey	20,100	120,000	5.95	21,200	145,000	6.85
New Mexico	13,800 r	90,200 r	6.56	16,000	112,000	7.01
New York	33,100	189,000	5.72	31,300	204,000	6.50
North Carolina	11,400 r	59,700	5.22 r	12,000	63,900	5.34
North Dakota	11,700 r	32,800	2.80	11,300	34,500	3.06
Ohio	50,800	263,000	5.19	51,700	288,000	5.58
Oklahoma	12,000	53,700	4.49	13,300	65,000	4.88
Oregon	20,700 r	125,000	6.04 r	22,000	146,000	6.63
Pennsylvania	19,900 r	126,000 r	6.35 r	17,000	111,000	6.55
Rhode Island	2,490	22,000	8.85 r	2,510	23,000	9.16
South Carolina	9,960	35,100	3.52	11,100	45,200	4.06
South Dakota	13,900 r	51,400 r	3.70 r	12,800	45,500	3.55
Tennessee	7,830	47,500	6.06	7,570	51,500	6.80
Texas	81,700	436,000	5.34	80,700	472,000	5.84
Utah	30,000 r	125,000	4.17 r	33,900	149,000	4.42
Vermont	4,970	24,000	4.82	5,240	32,000	6.11
Virginia	12,800	75,800	5.92	12,000	85,800	7.13
Washington	41,500	227,000	5.46	47,200	282,000	5.97
West Virginia	524	2,500	4.78	318	1,630	5.12
Wisconsin	43,400	178,000	4.11	43,200	191,000	4.41
Wyoming	10,500 r	40,700 r	3.88 r	11,700	52,400	4.49
Total or average	1,240,000	6,600,000 r	5.32 r	1,270,000	7,460,000	5.86

rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 6
CONSTRUCTION SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES IN 2005, BY MAJOR USE[1]

Use	Quantity (thousand metric tons)	Value (thousands)	Unit value
Concrete aggregates (including concrete sand)	294,000	$1,980,000	$6.74
Plaster and gunite sands	14,000	137,000	9.82
Concrete products (blocks, bricks, pipe, decorative, etc.)	5,020	44,300	8.82
Asphaltic concrete aggregates and other bituminous mixtures	77,900	572,000	7.33
Road base and coverings	140,000	757,000	6.40
Road stabilization, cement	5,270	24,400	4.64
Road stabilization, lime	1,180	6,780	5.74
Fill	92,200	363,000	3.94
Snow and ice control	6,020	32,000	5.32
Railroad ballast	1,280	13,200	10.36
Roofing granules	140	1,380	9.82
Filtration	1,510	10,100	6.66
Other miscellaneous uses	13,300	105,000	7.88
Unspecified:[2]			
Actual	304,000	1,740,000	5.71
Estimated	317,000	1,680,000	5.31
Total or average	1,270,000	7,460,000	5.86

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Reported and estimated production without a breakdown by end use.

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TABLE 7
CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY GEOGRAPHIC DIVISION AND MAJOR USE[1]

(Thousand metric tons and thousand dollars)

Region/division	Concrete aggregates (including concrete sand)		Plaster and gunite sands		Concrete products (blocks, bricks, pipe decorative, etc.)		Asphaltic concrete aggregates and other bituminous mixtures		Road base and coverings[2]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Northeast:										
New England	6,320	57,500	244	2,550	347	2,830	2,870	21,900	5,850	33,900
Middle Atlantic	13,700	106,000	393	3,190	490	4,990	7,270	48,600	6,930	39,400
Midwest:										
East North Central	44,700	226,000	484	3,090	1,290	5,950	14,000	70,900	20,900	106,000
West North Central	19,300	93,400	378	2,160	569	4,530	8,290	40,000	22,900	74,300
South:										
South Atlantic	42,200	283,000	2,400	14,900	740	4,970	2,240	13,500	3,100	26,100
East South Central	21,800	116,000	481	4,240	282	1,730	4,680	32,100	2,130	9,100
West South Central	45,700	294,000	889	4,900	373	2,800	2,640	17,200	7,460	44,500
West:										
Mountain	33,800	224,000	1,350	12,700	122	688	12,900	104,000	46,000	221,000
Pacific	66,000	578,000	7,340	89,300	803	15,800	23,000	224,000	31,400	234,000
Total	294,000	1,980,000	14,000	137,000	5,020	44,300	77,900	572,000	147,000	788,000

	Fill		Snow and ice control		Railroad ballast		Other uses[3]		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Northeast:										
New England	4,670	20,400	W	W	W	W	30,300	191,000	52,100	341,000
Middle Atlantic	5,930	26,400	1,550	7,240	40	499	33,200	223,000	69,500	460,000
Midwest:										
East North Central	19,700	72,400	1,300	5,230	13	53	123,000	577,000	225,000	1,070,000
West North Central	6,640	19,500	493	2,310	22	165	76,000	348,000	135,000	585,000
South:										
South Atlantic	11,400	38,400	147	1,020	--	--	36,800	202,000	99,000	584,000
East South Central	1,660	6,060	11	34	--	--	17,100	93,000	48,200	262,000
West South Central	9,080	26,200	W	W	W	W	57,100	321,000	123,000	712,000
West:										
Mountain	10,500	38,500	393	2,750	789	8,770	172,000	905,000	278,000	1,520,000
Pacific	22,500	115,000	553	2,460	336	2,670	90,500	674,000	242,000	1,940,000
Total	92,200	363,000	6,020	32,000	1,280	13,200	636,000	3,540,000	1,270,000	7,460,000

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes road and other stabilization (cement and lime).

[3]Includes reported and estimated production without a breakdown by end use.

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TABLE 8A
CONSTRUCTION SAND AND GRAVEL PRODUCTION IN THE UNITED STATES IN 2005, BY REGION AND SIZE OF OPERATION

Size range (metric tons)	U.S. total			
	Number of operations	Percentage of total	Quantity[1] (thousand metric tons)	Percentage of total
Less than 25,000	1,334	22.2	13,200	1.0
25,000 to 49,999	878	14.5	29,400	2.3
50,000 to 99,999	1,058	17.5	68,700	5.4
100,000 to 199,999	977	16.3	126,000	9.9
200,000 to 299,999	510	8.5	113,000	8.9
300,000 to 399,999	317	5.2	99,900	7.8
400,000 to 499,999	197	3.3	79,400	6.2
500,000 to 599,999	169	2.8	83,600	6.6
600,000 to 699,999	111	1.8	65,500	5.1
700,000 to 799,999	89	1.5	60,500	4.8
800,000 to 899,999	77	1.3	58,900	4.6
900,000 to 999,999	53	0.9	45,300	3.5
1,000,000 to 1,499,999	133	2.2	147,000	11.6
1,500,000 to 1,999,999	56	0.9	87,200	6.9
2,000,000 to 2,499,999	29	0.5	59,200	4.7
2,500,000 and more	41	0.6	136,000	10.7
Total	6,029	100	1,270,000	100

[1]Data are rounded to no more than three significant digits.

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TABLE 8B
CONSTRUCTION SAND AND GRAVEL PRODUCTION IN THE UNITED STATES IN 2005, BY REGION AND SIZE OF OPERATION

	Northeast				Midwest			
Size range (metric tons)	Number of operations	Percentage of total	Quantity[1] (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity[1] (thousand metric tons)	Percentage of total
Less than 25,000	288	29.5	2,790	2.3	459	21.3	4,570	1.3
25,000 to 49,999	153	15.7	5,090	4.2	369	17.1	12,400	3.4
50,000 to 99,999	184	18.9	12,200	10.0	413	19.1	26,700	7.4
100,000 to 199,999	164	16.8	21,100	17.3	364	16.9	47,300	13.1
200,000 to 299,999	71	7.3	15,600	12.8	187	8.7	41,800	11.6
300,000 to 399,999	39	4.0	12,200	10.0	92	4.3	29,200	8.1
400,000 to 499,999	25	2.6	10,100	8.3	71	3.3	28,700	7.9
500,000 to 599,999	12	1.2	5,960	4.9	63	2.9	31,100	8.6
600,000 to 699,999	14	1.4	8,280	6.8	36	1.7	21,500	5.9
700,000 to 799,999	7	0.7	4,830	4.0	22	1.0	14,900	4.1
800,000 to 899,999	2	0.2	1,540	1.3	23	1.1	17,700	4.9
900,000 to 999,999	5	0.5	4,190	3.4	13	0.6	11,000	3.0
1,000,000 to 1,499,999	7	0.7	7,870	6.5	18	0.8	19,100	5.3
1,500,000 to 1,999,999	2	0.2	3,180	2.6	14	0.6	22,300	6.2
2,000,000 to 2,499,999	2	0.2	3,920	3.2	7	0.3	14,600	4.1
2,500,000 and more	1	0.1	2,860	2.4	6	0.3	18,400	5.1
Total	976	100	122,000	100	2,157	100	361,000	100

	South				West			
Size range (metric tons)	Number of operations	Percentage of total	Quantity[1] (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity[1] (thousand metric tons)	Percentage of total
Less than 25,000	182	17.6	2,040	0.8	405	21.8	3,770	0.7
25,000 to 49,999	114	11.0	3,890	1.4	242	13.0	8,040	1.5
50,000 to 99,999	177	17.0	11,500	4.2	284	15.3	18,300	3.5
100,000 to 199,999	163	15.7	21,000	7.8	286	15.4	37,400	7.2
200,000 to 299,999	91	8.8	20,000	7.4	161	8.7	35,800	6.9
300,000 to 399,999	89	8.6	28,400	10.5	97	5.2	30,100	5.8
400,000 to 499,999	35	3.4	14,000	5.2	66	3.5	26,700	5.1
500,000 to 599,999	36	3.5	18,000	6.6	58	3.1	28,500	5.5
600,000 to 699,999	18	1.7	10,400	3.8	43	2.3	25,400	4.9
700,000 to 799,999	27	2.6	18,300	6.8	33	1.8	22,500	4.3
800,000 to 899,999	18	1.7	13,600	5.0	34	1.8	26,000	5.0
900,000 to 999,999	15	1.4	12,900	4.8	20	1.1	17,200	3.3
1,000,000 to 1,499,999	46	4.6	49,300	18.2	62	3.3	71,100	13.6
1,500,000 to 1,999,999	11	1.1	16,700	6.2	29	1.6	45,100	8.7
2,000,000 to 2,499,999	6	0.6	12,200	4.5	14	0.8	28,400	5.5
2,500,000 and more	7	0.7	18,400	6.8	27	1.3	96,500	18.5
Total	1,035	100	271,000	100	1,861	100	521,000	100

[1]Data are rounded to no more than three significant digits.

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TABLE 9
CONSTRUCTION SAND AND GRAVEL SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY GEOGRAPHIC DIVISION AND METHOD OF TRANSPORTATION[1]

(Thousand metric tons)

Region/division	Truck	Rail	Water	Other	Not transported	Not specified	Total
Northeast:							
New England	17,600	--	--	145	3,220	31,100	52,100
Middle Atlantic	28,600	92	1,080	389	2,830	36,400	69,500
Midwest:							
East North Central	77,600	2,470	2,130	891	11,200	131,000	225,000
West North Central	41,100	1,080	1,620	130	6,870	83,800	135,000
South:							
South Atlantic	57,200	2,060	828	41	3,980	34,900	99,000
East South Central	19,600	529	4,920	47	2,460	20,600	48,200
West South Central	46,900	1,010	34	--	10,100	65,200	123,000
West:							
Mountain	78,500	1,500	--	87	17,000	181,000	278,000
Pacific	131,000	3,200	6,320	1,100	23,000	78,200	242,000
Total	498,000	11,900	16,900	2,830	80,700	663,000	1,270,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 10
NUMBER OF CONSTRUCTION SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 2005, BY GEOGRAPHIC DIVISION

	Mining operations on land					
Region/division	Stationary	Portable	Stationary and portable	No plants or unspecified	Dredging operations	Total active operations
Northeast:						
New England	181	212	48	29	--	470
Middle Atlantic	190	202	43	36	35	506
Midwest:						
East North Central	482	416	94	65	103	1,160
West North Central	264	408	35	49	241	997
South:						
South Atlantic	110	52	14	49	109	334
East South Central	115	23	8	12	57	215
West South Central	205	80	22	48	131	486
West:						
Mountain	384	590	93	117	17	1,201
Pacific[1]	322	198	71	37	32	660
Total	2,253	2,181	428	442	725	6,029

-- Zero.

[1]An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.

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TABLE 11
NUMBER OF CONSTRUCTION SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 2005, BY STATE

State	Mining operations on land				Dredging operations	Total active operations
	Stationary	Portable	Stationary and portable	No plants or unspecified		
Alabama	44	5	1	6	12	68
Alaska[1]	15	16	3	5	5	44
Arizona	94	81	29	10	5	219
Arkansas	34	10	1	2	8	55
California	189	84	32	16	16	337
Colorado	65	133	15	18	6	237
Connecticut	28	22	10	2	--	62
Delaware	3	1	--	1	3	8
Florida	16	5	1	2	35	59
Georgia	13	1	1	1	25	41
Hawaii	2	4	--	1	--	7
Idaho	30	82	4	17	4	137
Illinois	52	27	12	5	38	134
Indiana	86	21	16	8	23	154
Iowa	38	51	4	3	36	132
Kansas	17	28	1	11	56	113
Kentucky	10	--	3	1	9	23
Louisiana	19	9	1	8	56	93
Maine	51	71	9	15	--	146
Maryland	22	4	3	8	3	40
Massachusetts	56	28	8	1	--	93
Michigan	137	167	34	29	11	378
Minnesota	103	150	19	12	6	290
Mississippi	41	8	1	3	22	75
Missouri	31	9	7	--	32	79
Montana	53	70	8	14	--	145
Nebraska	13	16	--	6	110	145
Nevada	42	54	12	11	--	119
New Hampshire	19	43	10	2	--	74
New Jersey	28	8	3	--	17	56
New Mexico	33	51	5	18	--	107
New York	100	173	27	27	9	336
North Carolina	23	21	5	19	15	83
North Dakota	29	75	1	1	--	106
Ohio	109	40	16	8	30	203
Oklahoma	19	9	3	8	40	79
Oregon	43	25	10	6	4	88
Pennsylvania	62	21	13	9	9	114
Rhode Island	9	6	2	1	--	18
South Carolina	10	9	--	5	17	41
South Dakota	33	79	3	16	1	132
Tennessee	20	10	3	2	14	49
Texas	133	52	17	30	27	259
Utah	52	70	14	14	--	150
Vermont	18	42	9	8	--	77
Virginia	21	9	4	13	9	56
Washington	73	69	26	9	7	184
West Virginia	2	2	--	--	2	6
Wisconsin	98	161	16	15	1	291
Wyoming	15	49	6	15	2	87
Total	2,253	2,181	428	442	725	6,029

-- Zero.

[1]An undetermined number of operations leased from the Bureau of Land Management in Alaska are counted as one operation.

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TABLE 12
RECYCLED ASPHALT CONCRETE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY GEOGRAPHIC DIVISION[1]

Region/division	2004 Quantity (thousand metric tons)	2004 Value (thousands)	2004 Unit value	2005 Quantity (thousand metric tons)	2005 Value (thousands)	2005 Unit value
Northeast:						
New England	148	$817	$5.52	225	$1,870	$8.30
Middle Atlantic	108	645	5.97	76	370	4.87
Midwest:						
East North Central	840	3,300	3.93	233	1,110	4.76
West North Central	553	3,800	6.87	820	5,240	6.40
South:						
South Atlantic	402	1,940	4.83	404	2,140	5.31
East South Central	44	200	4.55	27	180	6.67
West South Central	18	100	5.56	5	35	7.00
West:						
Mountain	778	3,390	4.36	416	1,920	4.62
Pacific[2]	1,330	7,590	5.73	1,550	10,900	7.02
Total or average	4,220	21,800	5.17	3,750	23,700	6.33

[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.
[2]Includes Alaska.

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TABLE 13
RECYCLED ASPHALT CONCRETE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

State	2004			2005		
	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
Alabama	--	--	--	W	W	$6.67
Alaska	56	$343	$6.13	W	W	9.40
Arizona	139	608	4.37	W	W	7.00
California	1,100	6,200	5.65	1,220	8,460	6.91
Colorado	364	1,810	4.98	87	521	5.99
Connecticut	15	126	8.40	7	49	7.00
Idaho	60	218	3.63	16	69	4.31
Illinois	234	980	4.19	38	166	4.37
Indiana	--	--	--	27	147	5.44
Iowa	17	81	4.76	25	165	6.60
Kansas	1	9	9.00	9	99	11.00
Louisiana	--	--	--	W	W	7.72
Maine	78	335	4.29	88	697	7.92
Maryland	86	380	4.42	W	W	4.99
Massachusetts	23	100	4.35	16	164	10.25
Michigan	256	635	2.48	126	618	4.90
Minnesota	519	3,600	6.93	733	4,800	6.55
Mississippi	22	120	5.45	--	--	--
Montana	--	--	--	21	78	3.71
Nebraska	--	--	--	10	40	4.00
Nevada	2	11	5.50	W	W	5.37
New Hampshire	--	--	--	36	151	4.19
New Mexico	--	--	--	W	W	6.16
New York	108	645	5.97	76	370	4.87
North Carolina	210	985	4.69	197	924	4.69
North Dakota	4	14	3.50	W	W	4.08
Ohio	6	10	1.67	--	--	--
Oklahoma	18	100	5.56	--	--	--
Oregon	86	645	7.50	155	1,330	8.61
Rhode Island	23	224	9.74	W	W	11.08
South Carolina	99	490	4.95	111	662	5.96
South Dakota	11	100	9.09	28	82	2.93
Tennessee	23	80	3.48	--	--	--
Utah	205	697	3.40	W	W	3.41
Vermont	10	33	3.30	10	62	6.20
Virginia	8	84	10.50	W	W	10.12
Washington	87	407	4.68	128	699	5.46
Wisconsin	344	1,680	4.88	41	176	4.29
Wyoming	8	42	5.25	16	183	11.44
Total or average	4,220	21,800	5.17	3,750	23,700	6.33

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.

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TABLE 14
RECYCLED CEMENT CONCRETE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY GEOGRAPHIC DIVISION[1]

Region/division	2004 Quantity (thousand metric tons)	2004 Value (thousands)	2004 Unit value	2005 Quantity (thousand metric tons)	2005 Value (thousands)	2005 Unit value
Northeast:						
New England	151	$563	$3.73	108	$752	$6.96
Middle Atlantic	249	1,820	7.31	106	585	5.52
Midwest:						
East North Central	993	5,250	5.29	1,300	7,180	5.53
West North Central	620	3,690	5.95	1,040	5,280	5.05
South:						
South Atlantic	306	1,640	5.37	156	1,150	7.39
East South Central	--	--	--	1	2	2.00
West South Central	22	100	4.55	22	148	6.73
West:						
Mountain	358	1,990	5.54	548	2,390	4.36
Pacific[2]	1,380	8,920	6.48	1,320	9,580	7.24
Total or average	4,080	24,000	5.88	4,610	27,100	5.87

[r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.
[2]Includes Alaska.

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TABLE 15
RECYCLED CEMENT CONCRETE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

State	2004 Quantity (thousand metric tons)	2004 Value (thousands)	2004 Unit value	2005 Quantity (thousand metric tons)	2005 Value (thousands)	2005 Unit value
Alaska	--	--	--	W	W	$5.65
Arizona	3	$9	$3.00	98	$274	2.80
California	1,140	7,300	6.46	1,070	8,040	7.49
Colorado	306	1,760	5.76	200	1,240	6.22
Connecticut	3	27	9.00	3	25	8.33
Hawaii	--	--	--	W	W	6.80
Idaho	11	49	4.45	(2)	(2)	2.22
Illinois	286	1,540	5.37	354	2,050	5.80
Indiana	15	80	5.33	91	485	5.33
Iowa	24	138	5.75	58	435	7.50
Kansas	3	21	7.00	W	W	9.56
Maine	3	18	6.00	W	W	5.63
Maryland	241	1,350	5.58	W	W	5.47
Massachusetts	131	451	3.44	77	568	7.38
Michigan	520	2,710	5.21	688	3,880	5.64
Minnesota	571	3,490	6.11	970	4,690	4.84
Mississippi	--	--	--	1	2	2.00
Missouri	--	--	--	2	14	7.00
Montana	1	6	6.00	35	117	3.34
Nebraska	--	--	--	4	35	8.75
Nevada	20	111	5.55	W	W	2.17
New Mexico	--	--	--	W	W	5.23
New York	249	1,820	7.31	106	585	5.52
North Carolina	13	130	10.00	W	W	10.00
North Dakota	--	--	--	W	W	8.00
Ohio	52	361	6.94	25	159	6.36
Oregon	21	129	6.14	40	258	6.45
Rhode Island	7	48	6.86	--	--	--
South Carolina	2	15	7.50	W	W	10.60
South Dakota	23	44	1.91	--	--	--
Texas	22	100	4.55	22	148	6.73
Utah	16	47	2.94	1	3	3.00
Vermont	7	19	2.71	20	115	5.75
Virginia	50	154	3.08	W	W	8.50
Washington	221	1,490	6.75	182	1,120	6.13
Wisconsin	121	567	4.69	139	598	4.30
Wyoming	--	--	--	W	W	6.13
Total or average	4,080	24,000	5.88	4,610	27,100	5.87

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.
[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.
[2]Less than ½ unit.

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TABLE 16
U.S. EXPORTS OF CONSTRUCTION SAND AND GRAVEL IN 2005, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

	Sand		Gravel	
Country or Territory	Quantity	Value, f.a.s.[2]	Quantity	Value, f.a.s.[2]
North America:				
Canada	64	4,590	343	3,260
Guatemala	(3)	77	--	--
Mexico	9	2,170	3	402
Panama	2	326	(3)	12
Other[4]	6	572	7	232
Total	81	7,730	353	3,900
South America:			--	--
Brazil	3	692	--	--
Colombia	1	136	--	--
Peru	(3)	47	--	--
Venezuela	1	463	--	--
Other[5]	(3)	243	--	--
Total	5	1,580	--	--
Europe:				
Belgium	(3)	125	--	--
Denmark	1	396	--	--
Finland	(3)	24	1	71
France	(3)	39	--	--
Germany	1	1,030	--	--
Norway	(3)	3	8	459
Sweden	(3)	15	1	18
United Kingdom	1	471	(3)	72
Other[6]	4	1,160	4	138
Total	7	3,270	14	758
Asia:				
China	1	333	(3)	5
Japan	(3)	154	(3)	14
Korea, Republic of	(3)	64	(3)	42
Taiwan	34	6,300	14	69
Other[7]	1	508	--	--
Total	36	7,350	15	130
Oceania, other[8]	1	311	--	--
Middle East, other[9]	(3)	128	(3)	10
Africa, other[10]	7	2,990	--	--
Grand total	137	23,400	382	4,800

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship. Value of material at U.S. port of export; based on transaction price, including all charges incurred in placing material alongside ship.

[3]Less than ½ unit.

[4]Includes Anguilla, Aruba, The Bahamas, Barbados, Bermuda, British Virgin Islands, Cayman Islands, Costa Rica, the Dominican Republic, El Salvador, Grenada, Guadeloupe, Haiti, Honduras, Jamaica, the Netherlands Antilles, St. Lucia, Trinidad and Tobago, and Turks and Caicos Islands.

[5]Includes Argentina, Chile, and Ecuador.

[6]Includes Austria, Estonia, Ireland, Italy, Luxembourg, the Netherlands, Poland, Romania, Russia, Spain, Switzerland, and Turkey.

[7]Includes Afghanistan, Hong Kong, India, Indonesia, Japan, Malaysia, Pakistan, Singapore, and Thailand.

[8]Includes Australia, New Zealand, and Palau.

[9]Includes Israel, Kuwait, Lebanon, Qatar, and the United Arab Emirates.

[10]Includes Algeria, Angola, Egypt, Nigeria, St. Helena, Tunisia, and Zaire.

Source: U.S. Census Bureau.

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TABLE 17
U.S. IMPORTS FOR CONSUMPTION OF CONSTRUCTION SAND AND GRAVEL, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

	2004		2005	
Country or Territory	Quantity	Value, c.i.f.[2]	Quantity	Value, c.i.f.[2]
Antigua and Barbuda	34	441	19	268
Australia	33	1,170	17	1,270
Bahamas, The	170	1,890	213	3,570
Canada	3,910	41,900	4,310	50,200
China	4	1,630	84	10,400
Dominica	23	453	4	84
France	(3)	118	1	211
Japan	2	551	2	468
Mexico	548	3,690	2,460	14,000
Philippines	1	145	(3)	118
Other[4]	35	4,890	53	6,140
Total	4,760	56,900	7,160	86,800

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Cost, insurance, and freight. Value of material at U.S. port of entry; based on purchase price and includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.
[3]Less than ½ unit.
[4]Includes Belgium, the British Virgin Islands (2004), Dominican Republic (2005), Germany Haiti, Malaysia, Montserrat (2005), the Netherlands Antilles, New Zealand, Norway, Peru, Poland, Republic of South Africa, Sweden, and the United Kingdom.

Source: U.S. Census Bureau.

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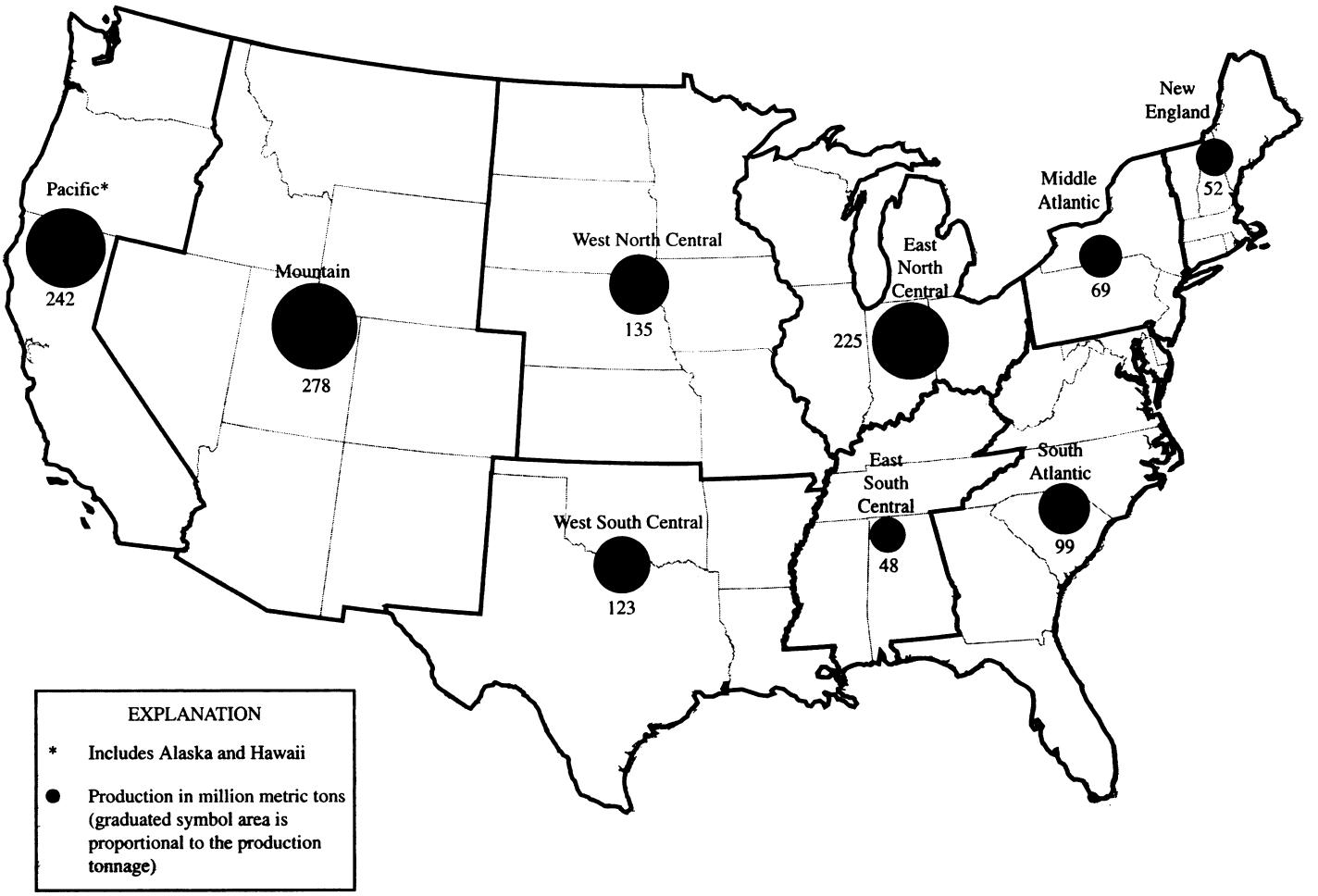
FIGURE 1
PRODUCTION OF CONSTRUCTION SAND AND GRAVEL IN THE UNITED STATES IN 2005, BY GEOGRAPHIC DIVISION



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SELENIUM AND TELLURIUM

By Micheal W. George

Domestic survey data and tables were prepared by Lisa D. Miller, statistical assistant, and the world production tables were prepared by Linder Roberts, international data coordinator.

One copper refinery in Texas reported domestic production of primary selenium and tellurium. One producer exported semirefined selenium for toll-refining in Asia, and two other companies generated selenium-containing slimes, which were exported for processing. In 2005, the price for selenium and tellurium increased as demand for the metals increased and global supplies became increasingly tight. Domestic production of primary selenium and tellurium decreased in 2005. Selenium and tellurium, rare elements widely distributed within the Earth's crust, do not occur in concentrations high enough to justify mining solely for their content. They are recovered as byproducts of nonferrous metal mining, mostly from the anode slimes associated with electrolytic refining of copper. Electrolytic refining of copper utilizes a sulfate-base electrolyte that does not dissolve precious and other base metals, allowing them to accumulate along with refractory components at the bottom of the electrolytic cell. The quantities of metals present in the slimes, such as bismuth, gold, selenium, silver, and tellurium, are dependent on their initial content in the copper anode material and, therefore, on the ores from which the copper concentrate originated.

Slimes resulting from primary copper metal refining can average 10% selenium by weight and in a few cases as much as 40%. Tellurium concentrations are generally lower and never exceed 5% (Weerts, 2002).

Selenium and tellurium can also be recovered economically from industrial scrap and chemical process residues. Obsolete and damaged photoreceptor drums from plain paper copy machines are shipped by manufacturers to refineries for recovery of selenium and tellurium metal.

The global production of selenium was estimated by industry to be about 2,700 metric tons (t) in 2005 and demand was estimated to be about 3,000 t. The imbalance has existed for a couple of years and has led to a drawdown of stocks of materials (Platts Metals Week, 2005).

Domestic Data Coverage

Domestic data are collected through a voluntary survey of U.S. selenium and tellurium producers. The production survey was sent to the two known domestic producers of selenium and the sole domestic producer of tellurium. All companies responded to the survey. In order to protect proprietary interests of the companies, survey data are withheld from publication.

Production

In the United States, ASARCO Incorporated's copper refinery in Amarillo, TX, was the only producer of refined selenium and tellurium. One copper refinery exported semirefined selenium (90% selenium content) for toll-refining in Asia. Two other refineries generated selenium-containing slimes, but did not produce selenium. Selenium-containing slimes from these refineries were exported for processing. Most of the primary selenium and tellurium recovered in the United States in 2005 came from copper ores in Arizona and Utah. Domestic production of refined selenium decreased in 2005 compared with that of 2004 owing to disruption in production at Asarco.

On July 2, 2005, Asarco workers began a strike that lasted for more than 4 months. In August 2005, the company filed for bankruptcy protection citing the extended strike and environmental cleanup costs as the causes. The strike ended in early November, and the company restarted operations. At yearend, the company was still in post-bankruptcy reorganization (Northern Miner, The, 2005; Berry, 2005§[1]).

Asarco produced commercial-grade tellurium at its refinery complex in Amarillo mainly from copper anode slimes but also from lead refinery skimmings. Asarco also produced high-purity tellurium, selenium, and compounds of these metals for specialty applications at its Globe plant in Denver, CO. Domestic refined tellurium production decreased in 2005 compared with that of 2004 owing to the supply disruptions at Asarco.

Consumption

Selenium.—World demand for selenium in 2005 was estimated to be higher than that in 2004, with the glass manufacturing industry being the leading consumer. Selenium is used to decolorize the green tint caused by iron impurities in glass containers and other soda-lime silica glass. It is also used in art and other glass, such as that used in traffic lights to produce a ruby red color and in architectural plate glass to reduce solar heat transmission through the glass.

Selenium was used as an alloy with bismuth to substitute for lead in plumbing in response to requirements of the Safe Drinking Water Act Amendments of 1996 (Public Law 104-182). The Act requires that effectively no lead be contained in any fixtures, fluxes, pipes, and solders used for the installation or repair of facilities that provide water for human consumption after August 1998. Metallurgical grade selenium is used as an additive to cast iron, copper, lead, and steel alloys. In these applications, it improves machinability and casting and forming properties.

The addition of a small amount, about 0.02% by weight, of selenium to low-antimony lead alloys used in the support grid of lead-acid batteries improves the casting and mechanical properties of the alloy.

[1]References that include a section mark (§) are found in the Internet References Cited section.

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Electronics were a diminishing end-use market in 2005. Photoreceptors on the drums of plain-paper copiers had been the largest single application for selenium during the 1970s and 1980s. Organic photoreceptor compounds (OPCs) have replaced these high-purity selenium compounds. OPCs are free of the environmental concerns involved with the disposal of selenium compounds and reportedly offer better performance and lower costs at lower printing speeds. While use in photoreceptors has been declining, other electronic uses for selenium, including rectifier and photoelectric applications, have been growing.

Chemical and pigment uses of selenium include industrial and pharmaceutical applications. Selenium added to fertilizer used in growing animal feed is the largest portion of this category. This practice is more common outside the United States, especially in countries with selenium-poor soils. Another method of increasing selenium in humans and livestock is through dietary supplements; however, this method puts less demand on global selenium supplies than other methods. Selenium's principal pharmaceutical use is in shampoo to control dermatitis and dandruff and as an antifungal agent.

Cadmium sulfoselenide compounds are used as pigments in ceramics, glazes, paints, and plastics. Selenium in pigments has good heat stability, reacts well to moisture, and is resistant to ultraviolet or chemical exposure. It can be used to produce a wide range of red, orange, and maroon colors, but because of the relatively high cost and the toxicity of cadmium-base pigments, their use is generally restricted to applications where they are uniquely suited.

Additionally, selenium is used in catalysts to enhance selective oxidation; in plating solutions, to improve appearance and durability; in blasting caps and gun bluing; in coating digital x-ray detectors; and in zinc selenide for infrared windows in carbon dioxide lasers (Amalgamet Canada, 2003§). In China, selenium dioxide (SeO_2) is substituted for sulfur dioxide to increase yields in the electrolytic production of manganese (Selenium-Tellurium Development Association, Inc., 2002§). By using SeO_2 instead of sulfur dioxide the plant reduces the power required to operate the electrolytic cells. This method requires about a kilogram of selenium per metric ton of manganese metal produced (Metal-Pages, 2004§).

Tellurium.—World demand for tellurium is thought to have increased in 2005. The leading use for tellurium was as a metallurgical alloying element. Tellurium was used in steel as a free-machining additive, in copper to improve machinability while not reducing conductivity, in lead to improve resistance to vibration and fatigue, in cast iron to help control the depth of chill, and in malleable iron as a carbide stabilizer.

Chemical and catalyst usage was the next largest end use. Tellurium was used as a vulcanizing agent and accelerator in the processing of rubber and as a component of catalysts for synthetic fiber production. Electrical uses were a smaller end use and consisted of photoreceptor and thermoelectric applications. Other end uses of tellurium were as an ingredient in blasting caps and as a pigment to produce blue and brown colors in ceramics and glass.

Tellurium catalysts are used chiefly for the oxidation of organic compounds but are also used in chlorination, halogenation, and hydrogenation reactions. Tellurium dioxide is used as a curing and accelerating agent in rubber compounds.

Consumption of tellurium in electronics applications was estimated to have increased in 2005. High-purity tellurium is used in electronics applications, such as thermoelectric and photoelectric devices. Thermal imaging devices use mercury-cadmium-telluride, which assists in converting a raw image into a crisp picture on the screen. Semiconducting bismuth telluride is used in thermoelectric cooling devices employed in electronics and consumer products. These devices consist of a series of couples of semiconducting materials which, when connected to a direct current, cause one side of the thermoelement to cool while the other side generates heat.

Thermoelectric coolers are most commonly used in military and electronics applications, such as the cooling of infrared detectors, integrated circuits, laser diodes, and medical instrumentation. Their application in consumer products, such as portable food-and-beverage coolers or automobile car seat cooling systems, continued to increase. Demand for solar cells increased in 2005 and with this, the consumption of tellurium. Several companies announced plans to expand production of solar cells within the next couple of years.

Prices

The Platts Metals Week's average New York dealer price for selenium was $51.43 per pound in 2005. The price, which had risen sharply in 2003, began 2005 at $36 to $40 per pound and rose through the first half of the year to a high of $52 to $56 per pound. The price remained at this level through most of the second half of the year but started to decline in December and ended the year at $46 to $49 per pound. The price volatility was attributed to fluctuating demand in China.

The United Kingdom price for lump and powder 99.95% tellurium, as published in Mining Journal, started the year at $20 to $25 per pound. The price range rapidly increased to a high of $130 to $180 per pound by midyear. The price dropped to $100 to $130 per pound at the beginning of August and remained relatively unchanged through yearend. Demand increases from China and solar cell manufacturers outside of China caused a supply shortfall and led to the price increases.

Trade

The export of selenium materials in 2005 increased by 59% compared with that of 2004. Top destinations for selenium were, in descending order, Germany, Hong Kong, Mexico, China, Australia, and the Philippines (table 2).

In 2005, imports of SeO_2 and unwrought waste and scrap increased by 43% to 589 t, compared with 2004 imports (table 3). In 2005, the United States had net imports of 335 t of selenium (including the selenium content of SeO_2) compared with 253 t in 2004. Belgium, Canada, the Philippines, Germany, and China (in order of decreasing quantity) accounted for about 90% of the imports of selenium metal and SeO_2 into the United States in 2005.

Imports of unwrought tellurium and tellurium waste and scrap, contained tellurium, decreased by 33% in 2005 compared with 62,800 kilograms (kg) in 2004 (table 5). The

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leading suppliers were Belgium, Canada, and China, in order of decreasing quantity, accounting for more than 95% of the total imports of tellurium metal into the United States. In 2005, tellurium exports increased by 750% compared with those of 2004 (table 4). The United Kingdom accounted for 77% of total exports.

World Review

Global selenium output cannot be easily determined because not all companies report production and because of the trade in semirefined production. Only about 20 of the approximately 80 copper refineries in operation around the world reported recovery of selenium, and less than one-half of that number reported tellurium refining (Selenium-Tellurium Development Association, Inc., 2002).

World refinery production of selenium, based on the countries listed in table 6, increased by about 4% to 1,390 t (table 5).

Belgium.—In 2005, Belgium-based Sidech increased production of selenium to about 180 t. The company is a leading producer of bismuth and started to increase its selenium production in 2004. The company bought intermediate and crude grade selenium raw materials and further refined these products to become a major supplier. Some of their production is counted as refined output in other countries. This is not new production and will probably not increase worldwide selenium production (Metal-Pages, 2005c§).

Canada.—Yukon Zinc Corporation (Vancouver, British Columbia, Canada) had mining equipment and a water license at its site and was expected to begin test mining the Wolverine zinc-silver deposit in the Yukon. The deposit has an unusually high level of selenium, which had previously been considered a negative factor until the rapid price increase and is now considered an asset (Metal-Pages, 2005d§).

Chile.—Corporacion Nacional del Corbre (Coldelco) was expecting to produce more copper in 2007. This increase in copper production will increase the availability of selenium and tellurium; however historically, Chilean deposits have a low selenium and tellurium content (Metal Bulletin, 2005b).

China.—China consumed much of the world's production of selenium. China depended on imports for about 95% of its needs and imported 781 t in 2005, an 11% drop compared with 2004 imports (Metal Bulletin, 2005a; Metal-Pages, 2006b§). The decrease in consumption was linked to major cutbacks in electrolytic manganese metal production owing to weak demand from the Chinese stainless steel industry (Metal-Pages, 2006a§). However, demand for selenium for the agriculture and glass industries remained steady (Metal-Pages, 2005c§).

Japan.—The major producers of selenium in Japan were Mitsubishi Materials Corporation; Nippon Mining & Metals Co., Ltd.; Shinko Kagaku Kogyo Co., Ltd.; and Sumitomo Metal Mining Co., Ltd. Selenium production increased by 4% in 2005 compared with that of 2004. Tellurium production in 2005 declined 31% compared with that of 2004. About 70% to 80% of Japanese production of selenium was exported owing to falling domestic demand caused by environmental regulations. Of the exports of selenium in 2005, 43% was exported directly to China. In 2005, stocks of selenium rose 72% and tellurium stocks declined 45% compared with levels in 2004 (Roskill's Letter from Japan, 2006a, c, d).

In the fiscal year 2004, Japanese secondary producers recovered 16 t of selenium and 600 kg of tellurium. Selenium and tellurium recovered by secondary producers rose by 36% and 40%, respectively, in fiscal year 2004 (Roskill's Letter from Japan, 2006b).

Current Research and Technology

Selenium's antioxidant and curative properties have been demonstrated to assist with a number of human health problems. The use of selenium as a dietary supplement has been shown to have a positive effect on the following health problems: acquired immune deficiency syndrome (AIDS), Alzheimer's disease, arthritis, asthma, cancer, cardiovascular diseases, pancreatitis, reproduction, thyroid function, and viral infections (Oldfield, 2003, p. 1-8). There were new developments for the use of selenium coatings on bandages, contact lenses, and medical devices. The selenium coatings act as antimicrobial, antineoplastic and antiviral agents and show promise as an antitumor growth agent (Selenium, Ltd., 2005§).

Several Japanese companies announced plans to produce solar panels made from copper, indium, gallium, and selenium (CIGS) for household use in Japan in 2007. Recent advancements in CIGS thin films have reduced production costs and improved performance as well as having reduced environmental impact during production (Metal-Pages, 2005a§). According to some industry analysts, the new solar power technology could increase the world consumption for selenium by 5% during the next 13 years (Metal Bulletin, 2006).

Outlook

The supply of selenium and tellurium is directly affected by the supply of the main product from which it is derived, copper, and to a lesser extent, by the supply of lead, nickel, or zinc where production is from a sulfide ore. Selenium and tellurium prices are often inversely related to the supply of copper. A byproduct of copper refining, selenium prices typically fall during periods of high copper production. Since selenium and tellurium prices do not influence copper production, an increase in selenium demand is not likely to cause an increase in the production of copper and its byproducts.

Though the global production of primary refined copper was projected to grow slightly in 2006, much of the increase is expected to come from the leaching and electrowinning of copper ores, a process that does not provide for the recovery of contained selenium and tellurium, and increases in copper production in South America, where ores have low selenium and tellurium content (Metal-Pages, 2005c§). Therefore global selenium and tellurium production will probably remain relatively unchanged, but domestic production is expected to increase owing to the end of an extended strike at Asarco, the main domestic producer of selenium and tellurium.

Chinese demand for selenium is expected to decline owing to a potential reduction in demand from manganese producers because of the reduction in manganese production in China and

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the rising costs of selenium and electricity. As for the phasing out of SeO_2 used for manganese production, the Chinese simply cannot afford to switch technologies (Metal-Pages, 2005b§, c§).

As with the Chinese manganese industry, world consumption for selenium in photoreceptors is likely to continue to decline as the cost of substituting organic compounds decreases. Promising prostate cancer research and other health benefits may eventually lead to increased consumption of the metal. Dosages taken directly for human consumption will not create large increases in demand for the metal because only minute quantities are necessary for effective therapy. Nevertheless, there could be a relatively large consumption increase if selenium is increasingly applied to the soil for crops to be consumed by humans or livestock. World consumption for selenium from the glass and steel industries will probably remain flat, as there are few substitutes.

Tellurium supply and demand had remained in fairly close balance for a decade. However, in 2004 and 2005, demand outstripped supply, causing the price to climb rapidly. In 2006, tellurium consumption was expected to increase further, chiefly from the solar cell industry. Production was expected to remain relatively unchanged, extending the supply shortfall.

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TABLE 1

SALIENT SELENIUM AND TELLURIUM STATISTICS[1]

(Kilograms, contained metal, and dollars per pound)

	2001	2002	2003	2004	2005
Selenium:					
United States:					
Production, primary refined	W	W	W	W	W
Shipments to consumers	W	W	W	W	W
Exports	41,200	86,700	249,000	160,000	254,000
Imports for consumption	483,000	422,000	367,000	412,000	589,000
Apparent consumption, metal	W	W	W	W	W
Dealers' price, average, commercial grade[2]	$3.80	$4.27	$5.68	$24.89	$51.43
World, refinery production	1,420,000 r	1,370,000 r	1,440,000 r	1,330,000	1,390,000 e
Tellurium, United States:					
Exports	7,970	3,510	10,200	6,160	52,400
Imports for consumption	28,000	28,100	48,900	62,800	42,200
Price at yearend, commercial grade[3]	$7.00	$7.00	$10.00	$22.50	$110.00

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits, except prices.

[2]Source: Platts Metals Week. Calculated from published price ranges.

[3]Average yearend price published by Mining Journal for United Kingdom lump and powder, 99.95% tellurium.

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TABLE 2
U.S. EXPORTS OF SELENIUM[1]

Country	2004 Quantity (kilograms, contained Se)	2004 Value	2005 Quantity (kilograms, contained Se)	2005 Value
Australia	22,800	$497,000	20,000	$86,100
Belgium	--	--	9,010	140,000
Brazil	1,660	21,000	4,470	69,300
Canada	1,570	46,600	378	11,400
China	4,930	13,300	25,000	320,000
Colombia	1,630	13,500	--	--
Costa Rica	2,030	31,400	1,530	23,700
El Salvador	3,400	52,700	--	--
Finland	3,750	88,000	--	--
France	--	--	9,770	42,900
Germany	23,900	669,000	49,600	314,000
Guatemala	--	--	6,600	102,000
Hong Kong	7,570	117,000	48,800	756,000
India	--	--	429	10,300
Indonesia	--	--	140	7,120
Italy	1,070	16,500	--	--
Japan	3,850	78,500	424	6,580
Korea, Republic of	440	5,400	--	--
Malaysia	2,450	38,000	--	--
Mexico	26,700	415,000	34,000	535,000
Netherlands	7,750	120,000	2,130	33,000
Philippines	25,200	390,000	15,900	246,000
Singapore	10,500	72,500	4,310	60,900
South Africa	--	--	447	9,260
Sweden	--	--	1,180	18,300
Taiwan	40	4,360	1,030	16,400
Thailand	4,100	38,800	8,550	74,700
United Kingdom	1,900	50,300	355	5,500
Venezuela	2,300	35,600	9,600	149,000
Total	160,000	2,810,000	254,000	3,040,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF SELENIUM[1]

Class and country	2004 Quantity (kilograms, contained Se)	2004 Value	2005 Quantity (kilograms, contained Se)	2005 Value
Selenium:				
Australia	--	--	1,980	$59,400
Belgium	160,000	$7,310,000	304,000	17,700,000
Canada	90,100	3,280,000	103,000	5,410,000
China	--	--	37,800	1,170,000
Czech Republic	1,050	46,800	--	--
France	--	--	3,690	168,000
Germany	15,700	688,000	29,300	3,080,000
Hong Kong	--	--	2,000	191,000
India	17,000	314,000	4	10,600
Japan	3,550	178,000	13,600	975,000
Korea, Republic of	500	28,100	17,400	713,000
Mexico	12,300	172,000	--	--
Netherlands	6,070	271,000	5,740	265,000
New Zealand	--	--	--	--
Peru	960	26,500	3,830	388,000
Philippines	79,700	2,880,000	41,500	3,030,000
Russia	14	8,100	10	9,940
Serbia and Montenegro	231	14,700	--	--
United Kingdom	14,700	734,000	10,200	683,000
Total	402,000	16,000,000	575,000	33,900,000
Selenium dioxide:[2]				
Germany	6,880	221,000	10,800	930,000
India	2,130	40,100	1,250	93,000
Japan	1,190	27,300	1,500	99,000
Philippines	--	--	500	59,400
Spain	71	4,330	--	--
United Kingdom	--	--	20	4,280
Total	10,300	293,000	14,100	1,190,000
Grand total	412,000	16,200,000	589,000	35,100,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Totals revised to 71% of original quantities and values.

Source: U.S. Census Bureau.

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TABLE 4
U.S. EXPORTS OF TELLURIUM[1]

Class and country	2004 Quantity (kilograms, contained Te)	2004 Value	2005 Quantity (kilograms, contained Te)	2005 Value
Belgium	220	$33,000	3,500	$270,000
Brazil	--	--	110	8,000
Canada	542	25,500	--	--
France	--	--	157	127,000
Germany	301	188,000	114	130,000
Hong Kong	--	--	543	60,700
Japan	2,310	318,000	3,020	364,000
Korea, Republic of	136	6,450	68	7,770
Mexico	50	7,450	--	--
Philippines	1,300	195,000	4,150	622,000
Spain	1,000	58,600	490	118,000
Taiwan	287	10,400	--	--
United Kingdom	8	13,100	40,200	2,460,000
Total	6,160	856,000	52,400	4,170,000

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF TELLURIUM[1]

Class and country	2004 Quantity (kilograms, contained Te)	2004 Value	2005 Quantity (kilograms, contained Te)	2005 Value
Belgium	15,100	$461,000	23,500	$1,910,000
Canada	15,800	1,280,000	11,500	1,330,000
China	115	30,500	5,250	1,190,000
Germany	16,400	232,000	267	38,300
India	695	32,100	79	3,670
Japan	126	80,600	40	67,100
Philippines	6,430	272,000	--	--
Russia	1	3,620	23	4,180
Ukraine	2	7,570	1,460	108,000
United Kingdom	8,120	222,000	31	9,200
Total	62,800	2,620,000	42,200	4,650,000

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 6

SELENIUM: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Kilograms, contained selenium)

Country[3]	2001	2002	2003	2004	2005[e]
Belgium[e]	200,000	200,000	200,000	200,000	200,000
Canada[4]	238,000	175,000	253,000	277,000 r	300,000
Chile[e]	85,000 r	80,000 r	83,000 r	82,000 r	82,000
Finland	38,913	39,237	49,163 r	61,256 r	62,000
Germany[e]	15,000 r	16,000 r	14,000 r	14,000 r	14,000
India[e, 5]	11,500	11,500	12,000	12,000	13,000
Japan	735,089	752,099	733,973	599,170 r	634,500 [6]
Peru	16,110 r	20,600	20,600 e	21,000 r	21,000
Philippines[e]	40,000	40,000	40,000	40,000	40,000
Serbia and Montenegro	20,000 e	15,000 e	10,000	5,000 r, e	--
Sweden[e]	20,000	20,000	20,000	20,000	20,000
United States	W	W	W	W	W
Total	1,420,000 r	1,370,000 r	1,440,000 r	1,330,000	1,390,000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in total. -- Zero.

[1]World totals, U.S. data, and estimated data have been rounded to three significant digits; may not add to totals shown.

[2]Insofar as possible, data relate to refinery output only; thus, countries that produced selenium contained in copper ores, copper concentrates, blister copper, and/or refinery residues but did not recover refined selenium from these materials indigenously were excluded to avoid double counting. Table includes data available through May 27, 2006.

[3]In addition to the countries listed, Australia, Iran, Kazakhstan, Russia, the United Kingdom, and Uzbekistan produced refined selenium, but output is not reported, and available information is inadequate for formulation of reliable estimates of output levels. Australia is known to produce selenium in intermediate metallurgical products and has facilities to produce elemental selenium. In addition to having facilites for processing imported anode slimes for the recovery of selenium and precious metals, the United Kingdom has facilities for processing selenium scrap.

[4]Excludes selenium intermediates exported for refining.

[5]Data are for Indian fiscal year beginning April 1 of year stated.

[6]Reported figure.

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TABLE 7

TELLURIUM: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Kilograms, contained tellurium)

Country	2001	2002	2003	2004	2005[e]
Canada[3]	51,000	39,000	40,000	69,000 [r]	75,000
Japan	39,008	28,656	33,154	32,703	22,200
Peru	19,105	21,600	22,000	22,000 [r]	22,000
United States	W	W	W	W	W

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Estimated data are rounded to no more than three significant digits.

[2]Insofar as possible, data relate to refinery output only; thus, countries that produced tellurium contained in copper ores, copper concentrates, blister copper and/or refinery residues, but did not recover refined tellurium are excluded to avoid double counting. Table is not totaled because of exclusion of data from major world producers. In addition to the countries listed, Australia, Belgium, Chile, Germany, the Philippines, Kazakhstan, and Russia are known to produce refined tellurium, but output is not reported; available information is inadequate to formulate reliable estimates of output levels. Table includes data available through May 27, 2006.

[3]Excludes tellurium intermediates exported for refining.

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SILICA

By Thomas P. Dolley

Domestic survey data and tables were prepared by Nicholas A. Muniz, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

Four silica categories are covered in this report—industrial sand and gravel, quartz crystal (a form of crystalline silica), special silica stone products, and tripoli. Most of the stone covered in the special silica stone products section is novaculite. The section on tripoli includes tripoli and other fine-grained, porous silica materials, such as rottenstone, that have similar properties and end uses. Certain silica and silicate materials, such as diatomite and pumice, are covered in other chapters of the U.S. Geological Survey (USGS) Minerals Yearbook, volume I, Metals and Minerals. Trade data in this report are from the U.S. Census Bureau. All percentages in the report were computed using unrounded data.

Industrial Sand and Gravel

Total industrial sand and gravel production increased to 30.6 million metric tons (Mt) in 2005 and was the highest production total in the history of the U.S. industry (table 1). Compared with 2004, industrial sand production increased by 3.5%, and gravel production decreased by 11%.

Industrial sand and gravel, often called "silica," "silica sand," and "quartz sand," includes sands and gravels with high silicon dioxide (SiO_2) content. Some examples of end uses of these sands and gravels are in glassmaking and for abrasive filtration, foundry, hydraulic fracturing (frac), and silicon metal applications. The specifications for each use vary, but silica resources for most uses are abundant. In almost all cases, silica mining uses open pit or dredging methods with standard mining equipment. Except for temporarily disturbing the immediate area while operations are active, sand and gravel mining usually has limited environmental impact.

The production increase for silica sand followed several years of increasing demand for many uses, which included ceramics, chemicals, fillers (ground and whole-grain), filtration, flat and specialty glass, hydraulic fracturing, recreational, and roofing granules. The demand for silica gravel, which was mostly used for filtration and nonmetallurgical flux, experienced a significant decrease. Increases in the total production and value of silica can be attributed in part to an overall increase in demand and to growth in the economy, particularly the construction sectors, petroleum sector, and increased energy costs to the silica producers in 2005.

Legislation and Government Programs.—One of the most important issues affecting the industrial minerals industry in recent times has been the potential effect of crystalline silica on human health. Central to the ongoing and often heated debate has been the understanding of the regulations and the implementation of the measurements and actions taken to mitigate exposure to crystalline silica and, most significantly, appreciation of its impact on the future of many industries (Industrial Minerals, 1998a). The U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) has created a permissible exposure limit that stipulates the maximum amount of crystalline silica to which workers may be safely exposed during an 8-hour work shift (29 CFR §§1926.55, 1910.1000). The OSHA also presents guidelines and training for the proper handling of crystalline silica (U.S. Department of Labor, Occupational Safety and Health Administration, 2002§[1]).

Important news during 2005 centered on a silicosis litigation decision that continues to affect the industrial sand and gravel industry. In a decision against the plaintiffs by a Federal judge in re Silica Products Liability Litigation, 398 F.Supp.2d 563 (S.D. Texas June 30, 2005), defendants requested that the court examine the reliability of thousands of silicosis diagnoses under Federal Rule of Civil Procedure 702 and the analytical framework developed by Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S. 579 (1993). The court found that the plaintiffs were attempting to generate revenue through silicosis litigation as opposed to creating a procedure for compensating truly injured individuals, and sanctions relating to conduct were imposed on the plaintiffs' counsel. The OSHA recently found that deaths attributed to silicosis in the United States have declined steadily each year since the late 1960s to 187 in 1999 from 1,157 in 1968.

Production.—Domestic production data for industrial sand and gravel were developed by the USGS from a voluntary survey of U.S. producers. The USGS canvassed 73 producers with 151 operations known to produce industrial sand and gravel. Of the 151 surveyed operations, 136 (90%) were active, and 15 were idle. The USGS received responses from 108 operations, and their combined production represented 85% of the U.S. total. Production for the 43 nonrespondents was estimated, primarily on the basis of previously reported information supplemented with worker-hours reports from the U.S. Department of Labor's Mine Safety and Health Administration and information from State agencies.

The Midwest (East North Central and West North Central divisions) continued to lead the Nation with 42% of the 30.6 Mt of industrial sand and gravel produced in the United States, followed by the South (South Atlantic, East South Central, and West South Central divisions) with 37%, and the West (Pacific and Mountain divisions) with 12% (fig. 1, table 2).

The leading producing States were, in decreasing order, Illinois, Texas, Wisconsin, California, New Jersey, Michigan, Oklahoma, and Ohio (table 3). Their combined production represented 61% of the national total. States for which data have been withheld in table 3 are not included among the leading producers. Of the 34 States that produced silica in 2005, 22 had increased production, 10 had decreased production, and 2 had

[1]A reference that includes a section mark (§) is found in the Internet Reference Cited section.

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stable production compared with 2004. Illinois, Minnesota, and Pennsylvania reported the largest increases, and North Carolina, New Jersey, and Michigan reported the largest decreases.

Of the total industrial sand and gravel, 84% was produced by 48 operations, each with production of 200,000 metric tons per year (t/yr) or more (tables 4-5). The 10 leading producers of industrial sand and gravel were, in descending order, Unimin Corp., U.S. Silica Co., Fairmount Minerals Ltd., Oglebay Norton Industrial Sands Co., Badger Mining Corp., Simplot Industries Inc., Little Six Corp., Nugent Sand Co. Inc., Manley Brothers, Inc., and Sand Products Corp. Their combined production from 64 operations represented 83% of the U.S. total.

Consumption.—Industrial sand and gravel production reported by producers to the USGS was material sold to their customers or used by the producing companies. Stockpiled material is not reported until consumed or sold. Of the 30.6 Mt of industrial sand and gravel sold or used, 35% was consumed as glassmaking sand, and 18%, as foundry sand (table 6). Frac sand and sand for well packing and cementing consumed 14% of industrial sand and gravel production. Other important uses were building products (8%) and abrasive sand (3%).

Minable deposits of industrial sand and gravel occur throughout the United States, and successful mining companies are located near markets that have traditionally been in the Eastern United States. In some cases, consuming industries are specifically located near a silica resource. The automotive industry was originally located in the Midwest near clay, coal, iron, and silica resources. Therefore, foundry sands have been widely produced in Illinois, Indiana, Michigan, Ohio, and other Midwestern States. In 2005, more than 80% of foundry sand was produced in the Midwest.

Conversely, the glass industry located plants where it could minimize the shipping distance of finished glass products (for example, container or flat). Hence, glass plants were more evenly distributed. In 2005, 42% of glass sand was produced in the South; 31%, in the Midwest; 16%, in the West; and 11%, in the Northeast. To varying degrees, all silica production and sales are similarly influenced by the location of the consuming industries.

Producers of industrial sand and gravel were asked to provide statistics on the destination of silica produced at their operations. The producers were asked to list only the quantity of shipments (no value data were collected in this section of the questionnaire) and to which State or other location the material was shipped for consumption. The States that received the most industrial sand and gravel were Texas (9.2%), California (8.7%), Illinois (7.5%), Ohio (5.2%), New Jersey (5%), and Wisconsin (4%). Producers reported sending at least 821,000 t of silica to Canada and 439,000 t to Mexico (table 7). Because some producers did not provide this information, their data were estimated or assigned to the "Destination unknown" category. In 2005, 8.4% of industrial sand and gravel shipped by producers was assigned to that category.

The share of silica sold for all types of glassmaking as a percentage of all silica sold was 35%, the same compared with that of 2004. In 2005, sales to container glass manufacturers increased by 9% compared with those of 2004. On average, in the container glassmaking industry, silica accounts for 60% of raw materials used (Industrial Minerals, 2004b). The amount of sand consumed for fiberglass production decreased by 4% compared with that of 2004.

In 2005, sales of sand for flat glass production decreased by 8% compared with those of 2004. In the Midwest, consumption for flat glass decreased by 22%, and in the South, consumption decreased by 4%.

Specialty glass consists of many segments, but the largest portion comprises laboratory and lighting glass (for example, incandescent and fluorescent light bulbs). Specialty laboratory glass also makes up part of the components used in many segments of the electronics industry, including the production of optical fiber and semiconductors.

The U.S. fiberglass industry comprises four major insulation manufacturers and six major textile producers. Continuous glass fiber specifications are very strict. Batch grain-size control is very important, so ground silica (ultrafine powder) is used. Iron, potassium, and sodium oxide content is tightly controlled. The raw mix is fused at 1,600° C and then drawn through platinum bushings at 1,300° C. Various mineral wools are fabricated using basalt and diabase (rock wool), blast furnace slag (slag wool), or glass (glass wool) (Industrial Minerals, 1998c).

Silica is used in ceramics in ground and whole-grain forms. Generally, 22% to 32% of the ceramic body of sanitaryware (for example, sinks, toilets, urinals) consists of whole-grain silica. Ground silica is used to decrease viscosity and the expansion coefficient of ceramic glazes and ceramic materials in applications. A typical glaze composition consists of 25% quartz or silica. In 2005, 208,000 metric tons (t) of ground silica was used in ceramic production.

Advanced ceramics, such as silicon nitride and silicon carbide, represent a growing market for silica and silica-base chemicals. Silicon carbide is manufactured by cooking silica sand or crushed quartz and oil coke at 2,400° C in an electric furnace for several days; sawdust or rice husks are added to increase porosity. Because of the anthropomorphic thermal conductivity and expansion coefficient of silicon carbide, it is especially useful in the refractory industry (Industrial Minerals, 1998b). Applications for silicon carbide include composite bearings used in a variety of pumps or wear parts, such as dynamic pressure, seal rings, shafts, and slide bearings. The global market for silicon nitride, based on powder use, has been estimated to be 300,000 t/yr. Primary markets for hybrid bearings, which are based on silicon nitride and silicon carbide, have been aerospace components, dental drills, gyroscopes, machine tool spindles, and vacuum systems. Other markets for silicon nitride included cutting tools and engine components (Ceramic Industry, 1998).

Silica also is used in plastics as an extender, filler, and reinforcer. Whole-grain and ground silica are used in filler-type applications. Ground silica is used to thicken liquid systems, to avoid plateout in polyvinyl chloride, as a thixotropic and flatting agent, and in many other filler applications. Silica also is used in paint because it offers acid, scrubbing, and wear resistance. In 2005, consumption of whole-grain filler was 2.5 Mt, and ground silica for filler was 465,000 t.

Specialty silicas are produced primarily by means of chemical and thermal processing of natural silica or silicon metal or as a

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byproduct of other mineral or chemical processing. Although the USGS does not specifically collect information on specialty silicas, consumption does affect natural silica sales. Specialty silicas and silanes (silica chemicals) include colloidal silicas, fused silica, organofunctional silanes, precipitated silica, pyrogenic (fumed) silica, quartz, silica gels, silicones, and ultra-high-purity silica. These silicas are used in a variety of industries and products, which include abrasives, adhesives, beverages, catalysts, coatings, electronics, encapsulants, food, health care, optics, paper and packaging, plastics, refractories, rubber, sealants, specialty coatings, textiles, thermoplastics, wafer polishing, and water treatment. Additionally, surface modification with silanes can improve the performance of several types of mineral fillers used in plastics. For example, when treated with silanes, the performance of iron oxide mineral filler is greatly enhanced (Industrial Minerals, 2004a).

Fumed silica forms tridimensional polymers used as thixotropic agents in silicons and silanes and is widely used as a coating agent for filler-grade calcium carbonate (Industrial Minerals, 1998c). In table 6, industrial sand and gravel that would find its way into these specialty silicas is most likely reported by the producers in the categories "Sand, abrasives, chemicals, ground and unground," "Gravel, silicon, ferrosilicon," and possibly "Glassmaking, specialty." In 2005, silica sales for chemical production were 830,000 t, which was an increase of 8% compared with those of 2004. According to the USGS survey, reported sales of silica gravel for silicon and ferrosilicon production decreased by 11% in 2005 compared with those of 2004. The main uses for silicon metal are in the manufacture of silanes and semiconductor-grade silicon and in the production of aluminum alloys. Consumption may be down owing to new techniques in the field of semiconductors to enable manufacturers to deposit a thin, defect-free layer of single-crystal silicon on wafer-thin microchips in a gas containing silicon. This new technique has superseded the traditional method of creating a massive cylindrical ingot of silicon from a batch of molten silicon, the single large crystal having too many defects for current applications (Hutcheson, 2004). Another new technique involves deforming the crystal structure of silicon, a primary component of all electronic devices. The technique alters the properties of silicon so that the material will transmit an optical or light-based signal, possibly resulting in replacing electronic components with faster optical components. Modern computers may benefit from such improvements (Jacobsen and others, 2006).

Optical fiber production involves a series of highly sophisticated manufacturing methods. For the optical fiber, a glass core with a high refractive index surrounded by glass with a lower refractive index is required. This problem has been solved by using several manufacturing methods, such as producing the fiber with fused silica but doping its core with an element that increases the refractive index (Industrial Minerals, 1998b).

The high-purity fused silica used by the electronics industry is typically at least 99.95% SiO_2 and has a high electromagnetic radiation transparency, a very low expansion coefficient, and good insulation properties. Silica grain and powder products are mainly produced from fused silica, which is made from silica sands. Fused silica has characteristics similar to zircon and is often mixed with zircon to form casting shells (Industrial Minerals, 2002b).

Synthetic precipitated silica and silica gel are produced by reacting sodium silicate with hydrochloric acid. Precipitated silica has been used increasingly in tires, more so in Europe than in the United States. Through replacement of a portion of carbon black with precipitated silica in the tread, the reinforcing action of the silica particles extends tire life (Industrial Minerals, 2000b). European consumers prefer the "green" tires made with precipitated silica, which is used in 70% to 80% of tires for passenger cars in Europe (Industrial Minerals, 2000a).

Transportation.—Of all industrial sand and gravel produced, 64% was transported by truck from the plant to the site of first sale or use, up slightly from 2004; 34% was transported by rail, down slightly from 2004; and less than 1% by waterway.

Prices.—Compared with the average value of 2004, the average value, free on board plant, of U.S. industrial sand and gravel increased by 7% to $24.56 per metric ton in 2005 (table 6). The average unit values for industrial sand and industrial gravel were $24.69 per ton and $20.42 per ton, respectively. The average price for sand ranged from $6.75 per ton for metallurgical flux to $103.85 per ton for ground foundry sand. For gravel, prices ranged from $9.29 per ton for nonmetallurgical flux to $49.79 per ton for filtration. Producer prices reported to the USGS for silica commonly ranged from several dollars per ton to hundreds of dollars per ton, and occasionally prices exceeded the $1,000-per-ton level. Nationally, ground sand for foundry molding and core had the highest value ($103.85 per ton), followed by silica for swimming pool filters ($81.81 per ton), ground sand used as fillers for paint, putty, and rubber ($59.32 per ton), ground sand for ceramics ($50.30 per ton), ground sand for scouring cleansers ($47.96 per ton), silica for municipal water filtration ($46.02 per ton), sand for hydraulic fracturing ($43.45 per ton), and ground sand for fiberglass ($40.81 per ton).

By geographic region, the average value of industrial sand and gravel was highest in the South ($26.72 per ton), followed by the West ($26.05 per ton), the Midwest ($23.16 per ton), and the Northeast ($20.13 per ton) (table 6). Prices can vary greatly for similar grades of silica at different locations in the United States. For example, the average value of container glass sand varied from $22.37 per ton in the West to $12.02 per ton in the Midwest. Tighter supplies and higher production costs in the West and much greater competition in the Midwest caused the difference in the cost to the consumer of sand and gravel in these two regions.

Foreign Trade.—Exports of industrial sand and gravel in 2005 increased by 63% compared with the amount exported in 2004, and the associated value decreased by 12% (table 8). The large increase in exports can be attributed mainly to increased demand from Asian and North American markets. Canada was the leading recipient of U.S. exports. The distribution of exports was as follows: 73% to Canada, 10% to Japan, 9.6% to Mexico, 1.4% to Germany, and the remainder to Africa and the Middle East, Europe, South America, and Oceania. The average price of exports decreased to $53 per ton in 2005 from $97 per ton in 2004. In 2005, export prices varied widely by region; exports of higher grade silica to Europe averaged $557 per ton, and exports to the rest of the world averaged $40 per ton.

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Imports for consumption of industrial sand and gravel rose to 711,000 t, which was an increase of 45% compared with those of 2004 (table 9). Mexico supplied 54% of the silica imports, which averaged $10.66 per ton; this price included insurance and freight costs to the U.S. port. The total value of imports was $18.2 million, with an average of $24 per ton. Higher priced imports came from Australia, China, Germany, and Japan.

World Industry Structure.—Based on information provided mainly by foreign governments, world production of industrial sand and gravel was estimated to be 118 Mt (table 11). The United States was the leading producer followed, in descending order, by Slovenia, Germany, Austria, France, Spain, Japan, and the United Kingdom. Most countries in the world had some production and consumption of industrial sand and gravel, which are essential to the glass and foundry industries. Because of the great variation in reporting standards, however, obtaining reliable information was difficult. In addition to the countries listed, many other countries were thought to have had some type of silica production and consumption.

Outlook.—U.S. consumption of industrial sand and gravel in 2006 was expected to be 26 to 28 Mt. Consumption is expected to be 27 Mt. All forecasts are based on previous performances for this commodity within various end uses, contingency factors considered relevant to the future of the commodity, and forecasts made by analysts and producers in the various markets.

Sales of glass sand can be expected to vary from market to market. Growth has been noted in some segments, such as flat and specialty glasses, container glass, fiberglass, and frac sand. Total demand for all glass sand end uses is expected remain static or possibly exhibit slow growth, probably to the range of 10 to 11 Mt through 2006. Demand for industrial sand and gravel will also be constrained by the producer's rising energy costs for both production and transportation of product.

The demand for foundry sand is dependent mainly on automobile and light truck production. Another important factor for the future consumption of virgin foundry sand is the recycling of used foundry sand. The level of recycling is believed to be increasing. Other materials or minerals compete with silica as foundry sand, but these other "sands" usually suffer from a severe price disadvantage. Based on these factors, consumption of silica foundry sand in 2006 is expected to be 5 Mt, and consumption is expected to range from 5 to 5.3 Mt.

Frac sand sales increased in 2005 compared with those of 2004. Based on this trend, demand for frac sand is expected to increase modestly during 2006 to 4 Mt, with a range of 4 to 4.2 Mt.

The United States is the leading producer and a major consumer of silica sand and is self-sufficient in this mined commodity. Most of it is produced at premier deposits in the Midwest and near major markets in the Eastern United States. A significant amount of silica sand is also produced in the West and Southwest, mostly in California and Texas, respectively. Domestic production is expected to continue to meet 97% or 98% of demand well beyond 2006. Imports mostly from Canada and Mexico and higher valued material from China are expected to remain minor.

Because the unit price of silica sand is relatively low, except for a few end uses that require a high degree of processing, the location of a silica sand deposit in relation to the market is an important factor that may work for or against a sand producer. Consequently, a significant number of relatively small operations supply local markets with a limited number of products.

Several factors could affect supply and demand relations for silica sand. Further increases in the development of substitute materials for glass and cast metals could reduce demand for foundry and glass sand. These substitutes, which are mainly ceramics and polymers, would likely increase the demand for ground silica, which is used as a filler in plastics; glass fibers, which are used in reinforced plastics; and silica (chemical, ground, or whole-grain), which is used to manufacture ceramics. Increased efforts to reduce waste and to increase recycling also could lower the demand for mined glass sand. Recycling of glass cullet is increasing in most industrialized nations and recycling accounts for approximately 25% to 70% of the raw material needed for the glass container industry in many countries. It has been estimated that for every 10% of recycled glass cullet used in the melting process for glass container manufacture, energy use will fall approximately 2.5%. During the past 20 years, a 25% to 40% reduction in glass container weight has taken place in many nations, including the United States (Industrial Minerals, 2004b). Although developments could cause the demand for silica sand to decrease, the total value of production could increase because of the increased unit value of the more specialized sands.

Health concerns about the use of silica as an abrasive and stricter legislative and regulatory measures concerning crystalline silica exposure could reduce the demand in many silica markets. The use of silica sand in the abrasive blast industry was being evaluated as a health hazard as marketers of competing materials, which include garnet, olivine, and slags, encouraged the use of their "safer" abrasive media. Additionally, abrasive-grade bauxite, which is the feedstock for brown fused alumina, is finding increasing use in abrasives and proppants; in the latter application, bauxite is used to hold fractures open in oil wells, as is silica sand (Industrial Minerals, 2002a).

Quartz Crystal

Electronic-grade quartz crystal is single-crystal silica with properties that make it uniquely useful in accurate filters, frequency controls, and timers used in electronic circuits. These devices are used for a variety of electronic applications in aerospace hardware, commercial and military navigational instruments, communications equipment, computers, and consumer goods (for example, clocks, games, television receivers, and toys). Such uses generate practically all the demand for electronic-grade quartz crystal. A lesser amount of optical-grade quartz crystal is used for lenses and windows in specialized devices, which include some lasers.

Natural quartz crystal was used in most electronic and optical applications until 1971 when it was surpassed by cultured quartz crystal. It has been estimated that approximately 10 billion quartz crystals and oscillators will be manufactured and installed worldwide in all types of electronic devices, from automobiles to cell phones in 2006. Despite this staggering number, quartz technology could face competition in the near future with the advent of more cost effective microelectromechanical systems (MEMS). MEMS technology was first developed in 1965 and

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consists of silicon on insulated wafers. MEMS technology is physically compatible with existing quartz oscillator products and have better long-term stability performance characteristics for use in consumer and computational products, automotive, and wireless applications (Partridge, 2006).

The use of natural quartz crystal for carvings and other gemstone applications has continued; more information can be found in the "Gemstones" chapter of the USGS Minerals Yearbook, volume I, Metals and Minerals.

Legislation and Government Programs.—The strategic value of quartz crystal was demonstrated during World War II when it gained widespread use as an essential component of military communication systems. After the war, natural electronic-grade quartz crystal was officially designated as a strategic and critical material for stockpiling by the Federal Government. Cultured quartz crystal, which eventually supplanted natural crystal in nearly all applications, was not commercially available when acquisition of natural quartz crystal for a national stockpile began.

As of December 31, the National Defense Stockpile (NDS) contained 7,236 kilograms (kg) of natural quartz crystal. The stockpile has 11 weight classes for natural quartz crystal that range from 0.2 kg to more than 10 kg. The stockpiled crystals, however, are primarily in the larger weight classes. The larger pieces are suitable as seed crystals, which are very thin crystals cut to exact dimensions, to produce cultured quartz crystal. In addition, many of the stockpiled crystals could be of interest to the specimen and gemstone industry. Little, if any, of the stockpiled material is likely to be used in the same applications as cultured quartz crystal.

No natural quartz crystal was sold from the NDS in 2005. The Federal Government continues to assess its stockpile goals for the remaining material. Previously, only individual crystals in the NDS inventory that weighed 10 kg or more and could be used as seed material were sold. Brazil traditionally has been the source of such large natural crystals, but changes in mining operations have reduced output.

Quartz crystal is also affected by the regulation of crystalline silica as discussed in the "Legislation and Government Programs" portion of the "Industrial Sand and Gravel" section of this chapter.

Production.—The USGS collects production data for quartz crystal through a survey of the domestic industry. In 2005, no domestic companies reported the production of cultured quartz crystal. In the past several years, cultured quartz crystal was being predominantly produced overseas, primarily in Asia.

Companies produce cultured quartz crystal by using a hydrothermal process in large pressure vessels called autoclaves. Seed crystals are mounted on racks and suspended in the upper growth region of the vessel. Lascas, which is a high-purity natural quartz feedstock, is loaded in an open-mesh wire basket that is placed in the bottom of the autoclave. A solution of sodium hydroxide or sodium carbonate (the mineralizer) with such additives as lithium salts and deionized or distilled water is used to fill the vessel to 75% to 85% of its volume. The bottom half of the growing vessel is heated to temperatures averaging between 350° and 400° C; the temperature of the top portion is maintained at 5° to 50° C lower than that in the bottom half of the vessel, depending upon the mineralizer used. At these temperatures, the solution expands and creates internal pressure between 700 and 2,100 kilograms per square centimeter. Under these conditions, the lascas dissolves to create a solution saturated with silica. Through convection, the saturated solution transports dissolved silica to the cooler upper half of the vessel where it becomes supersaturated, and the excess dissolved quartz deposits on the seed crystals in the top half of the autoclave. The process continues until the growing crystals reach their desired size. The process normally takes from 30 to 60 days for a 1-inch-thick bar and longer for larger crystals; at least one producer has made runs of 180 days. The cultured crystals can be custom grown with specific properties.

Processing quartz crystal for various end uses is the same whether natural or cultured seed crystal is used. Producers, however, must avoid seed crystals with defects that could be passed on to new generations of cultured crystal. Natural quartz crystal is preferred as seed material to ensure that genetic defects will not be repeated in the succeeding generations.

Once produced, cultured crystals are examined for physical defects before cutting. They are then cut, usually with diamond or slurry saws, along a predetermined crystallographic plane to a thickness slightly larger than that desired. Each wafer is inspected and diced into blanks of the desired dimensions. The blanks then progress through a series of lapping stages until they reach the final thickness, electrodes are attached, and the crystals are mounted in suitable holders. The final assembly, which is called a quartz crystal unit, is ready for insertion into an electronic circuit.

Consumption.—In 2005, the USGS collected domestic consumption data for quartz crystal through a survey of 23 U.S. operations that fabricate quartz crystal devices in 9 States. Of the 23 operations, 9 responded to the survey. Consumption for nonrespondents was estimated based on reports from previous years.

Quartz crystal is used in piezoelectric and optical applications. The piezoelectric effect is achieved when a suitable electrical signal applied to a quartz wafer makes the wafer vibrate mechanically throughout the bulk of the material at a characteristic natural resonance frequency. Quartz resonators are uniquely suitable for aerospace, commercial, and military bandpass filter applications that require very high selectivity or for oscillator applications that require very high stability. In addition, for many applications that require only moderate stability, a quartz resonator offers a unique combination of high performance, small size, and low cost. Quartz resonators also are used for many less demanding applications, such as providing timing signals for electronic circuits in automotive, consumer, and industrial products.

Cultured quartz is used almost exclusively by the crystal device industry because of the cost advantages. For resonator applications, raw cultured quartz must be cut into thin wafers oriented precisely in line with raw material crystal axes. The uniformity and convenience of cultured quartz have made its use almost universal. Unlike cultured quartz, natural electronic-grade quartz requires special orientation, cutting, grading, and sizing to produce a quartz wafer. As a result, most device manufacturers that cut natural quartz in the past have discontinued its use. One of the remaining applications of the natural electronic-grade material is in pressure transducers used in deep wells.

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Quartz wafers must be cut thin for practical use at very high frequencies (above 100 megahertz). Quartz crystal structures that use surface vibrations, in which the frequency is determined by electrode dimensions rather than by wafer thickness, have become more prevalent at these higher frequencies. These structures are called surface acoustic wave devices.

Most optical applications use quartz in the fused form as silica glass. Small quantities of cultured quartz crystal are used directly in optical applications. Quartz crystal also has uses that involve birefringent filters, Brewster windows and prisms, normally polarized laser beams, quartz retardation plates (especially quartz wave plates), and tuning elements in laser optics.

Prices.—The average value of as-grown cultured quartz and lumbered quartz, which is as-grown quartz that has been processed by sawing and grinding, was estimated to be $156 per kilogram in 2005.

Foreign Trade.—The U.S. Department of Commerce (DOC), which is the major Government source of U.S. trade data, does not provide specific import or export statistics on lascas. The DOC also collects export and import statistics on electronic and optical-grade quartz crystal; however, the quartz crystal export and import quantities and values reported in previous years included zirconia and were inadvertently reported to be quartz crystal not including mounted piezoelectric crystals.

World Review.—Cultured quartz crystal production is concentrated in China, Japan, Russia, and the United States; several companies produce crystal in each country. Other producing countries are Belgium, Brazil, Bulgaria, France, Germany, South Africa, and the United Kingdom. Details concerning quartz operations in China, the Eastern European countries, and most nations of the Commonwealth of Independent States are unavailable. Operations in Russia, however, have significant capacity to produce synthetic quartz.

Outlook.—The trend toward importing quartz could have a negative effect on domestic quartz growers. Growth of the consumer electronics market (for example, automobiles, cellular telephones, electronic games, and personal computers), particularly in the United States, will continue to provide consumer outlets for domestic production. The growing global electronics market may require additional production capacity worldwide.

Special Silica Stone Products

Silica stone (another type of crystalline silica) products are materials for abrasive tools, such as deburring media, grinding pebbles, grindstones, hones, oilstones, stone files, tube-mill liners, and whetstones. These products are manufactured from novaculite, quartzite, and other microcrystalline quartz rock. This chapter, however, excludes products that are fabricated from such materials by artificial bonding of the abrasive grains (information on other manufactured and natural abrasives may be found in other USGS Minerals Yearbook, volume I, Metals and Minerals chapters).

Special silica stone is also affected by the regulation of crystalline silica as discussed in the "Legislation and Government Programs" part of the "Industrial Sand and Gravel" section of this chapter.

Production.—In response to a USGS production survey, four of seven domestic firms, representing 88% of crude production, responded during 2005. Data for the remaining producers were estimated. Arkansas accounted for most of the value and quantity of production reported. Plants in Arkansas manufactured files, deburring-tumbling media, oilstones, and whetstones (table 10).

The industry has produced and marketed four main grades of Arkansas whetstone in recent years. The grades range from the high-quality black hard Arkansas stone down to Washita stone. In general, the black hard Arkansas stone has a porosity of 0.07% and a waxy luster, and Washita stone has a porosity of 16% and resembles unglazed porcelain.

Consumption.—The domestic consumption of special silica stone products is by a combination of craft, household, industrial, and leisure uses. The leading household use is for sharpening of knives and other cutlery, lawn and garden tools, scissors, and shears. Major industrial uses include deburring of metal and plastic castings, polishing of metal surfaces, and sharpening and honing of cutting surfaces. The major recreational use is in sharpening of arrowheads, fishhooks, spear points, and sports knives. The leading craft application is sharpening tools for engraving, jewelry making, and woodcarving. Silica stone files are also used in the manufacture, modification, and repair of firearms.

Prices.—The average value of crude material suitable for cutting into finished products was $989 per ton. The average value of stone products made from crude material was $3.97 per kilogram (table 1).

Foreign Trade.—In 2005, silica stone product exports had a value of $10 million, up from that of 2004. These exports were categorized as "hand sharpening or polishing stones" by the DOC. This category accounted for most, if not all, of the silica stone products exported in 2005.

In 2005, the value of imported silica stone products was $7.7 million; this was an increase of 12.9% compared with that of 2004. These imports were hand sharpening or polishing stones, which accounted for most of or all the imported silica stone products in 2005. A portion of the finished products that were imported may have been made from crude novaculite produced in the United States and exported for processing.

Outlook.—Consumption patterns for special silica stone are not expected to change significantly during the next several years. Most of the existing markets are well defined, and the probability of new uses is low.

Tripoli

Tripoli, broadly defined, includes extremely fine grained crystalline silica in various stages of aggregation. Grain sizes usually range from 1 to 10 micrometers (μm), but particles as small as 0.1 to 0.2 μm are common. Commercial tripoli contains 98% to 99% silica and minor amounts of alumina (as clay) and iron oxide. Tripoli may be white or some shade of brown, red, or yellow depending upon the percentage of iron oxide.

Tripoli also is affected by the regulation of crystalline silica as discussed in the "Legislation and Government Programs" part of the "Industrial Sand and Gravel" section of this chapter.

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Production.—In 2005, five U.S. firms were known to produce and process tripoli. American Tripoli Co. produced crude material in Ottawa County, OK, and finished material in Newton County, MO. Keystone Filler and Manufacturing Co. in Northumberland County, PA, processed rottenstone, which is decomposed fine-grained siliceous shale purchased from local suppliers. Malvern Minerals Co. in Garland County, AR, produced crude and finished material from novaculite. Harbison-Walker Refractories Co. Inc. in Hot Springs County, AR, produced crude and finished tripoli that is consumed in the production of refractory bricks and shapes. Unimin Specialty Minerals Inc. in Alexander County, IL, produced crude and finished material. All these firms except one responded to the USGS survey.

Consumption.—The 2005 USGS annual survey of producers indicated that sales of processed tripoli decreased by 3% in quantity to 91,000 t with a value of $18.7 million (table 1).

Tripoli has unique applications as an abrasive because of its hardness and its grain structure, which lacks distinct edges and corners. It is a mild abrasive, which makes it suitable for use in toothpaste and tooth-polishing compounds, industrial soaps, and metal- and jewelry-polishing compounds. The automobile industry uses it in buffing and polishing compounds for lacquer finishing.

The end-use pattern for tripoli has changed significantly in the past 30 years. In 1970, nearly 70% of the processed tripoli was used as an abrasive. In 2005, 12% of tripoli output was used as an abrasive. The remainder was used in brake friction products, as a filler and extender in enamel, caulking compounds, linings, paint, plastic, refractories, rubber, and other products.

The primary use of tripoli (84%) is as a filler and extender in paints. In exterior latex paints, tripoli also aids in durability, flowability, leveling, and tint retention. In enamels, it makes application easier and improves sheen. The controlled grain and particle size of tripoli in paints improves dispersal and promotes a more uniform coating. Additionally, paints with tripoli resist chemical agents and wear better than those in which water-ground whitings and other softer or more reactive fillers are used.

Plastics, resins, and rubbers each account for 5% of the tripoli used as a filler and extender. Tripoli is used in plastics for electrical uses because of its dielectric characteristics and its effects on compression and flexibility properties. Its chemical resistance, resistance to salt spray, and weatherability also are important to its use in plastics. The physical properties of tripoli allow high frictional loading in most compounds, but its abrasiveness results in high wear in extruding nozzles and molds. The same properties that make tripoli useful as a filler and extender in plastic make it valuable to the rubber and resin industries.

Price.—The average reported unit value of all tripoli sold or used in the United States was $206 per ton in 2005. The average reported unit value of abrasive tripoli sold or used in the United States during 2005 was $197 per ton, and the average reported unit value of filler tripoli sold or used domestically was $209 per ton.

Outlook.—Consumption patterns for tripoli are not expected to change significantly during the next several years. Most of the existing markets are well defined, and the probability of new uses is low.

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TABLE 1
SALIENT U.S. SILICA STATISTICS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

		2001	2002	2003	2004	2005
Industrial sand and gravel:[2]						
Sold or used:						
Quantity:						
Sand		26,900	25,900	26,300	28,700	29,700
Gravel		1,060	1,420	1,140	1,070	955
Total		27,900	27,300	27,500	29,700	30,600
Value:						
Sand		559,000	554,000	594,000	668,000	733,000
Gravel		17,600	19,400	15,300	16,600	19,500
Total		576,000	573,000	609,000	685,000	752,000
Exports:						
Quantity		1,540	1,410	2,620	1,790	2,910
Value		163,000	145,000	155,000	174,000	154,000
Imports for consumption:						
Quantity		172	250	440	490	711
Value		11,000	8,650	9,210	12,400	18,200
Processed tripoli:[3]						
Quantity	metric tons	60,500	66,600	68,800	94,000	91,100
Value		15,000	16,600	17,700	19,400	18,700
Special silica stone:						
Crude production:						
Quantity	metric tons	705	748	1,070	227	193
Value		234	240	313	132	191
Sold or used:						
Quantity	metric tons	393	386	513	655	576
Value		4,040	3,740	3,630	3,660	2,290

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Excludes Puerto Rico.
[3]Includes amorphous silica and Pennsylvania rottenstone.

TABLE 2
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY GEOGRAPHIC DIVISION[1]

	2004				2005			
Geographic region	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Value (thousands)	Percentage of total
Northeast:								
New England	W	W	W	W	W	W	W	W
Middle Atlantic	2,760	9	$53,300	8	2,720	9	$54,800	7
Midwest:								
East North Central	9,990	34	193,000	28	10,600	35	223,000	30
West North Central	2,030	7	57,300	8	2,240	7	74,300	10
South:								
South Atlantic	4,460	15	92,700	14	4,080	13	96,800	13
East South Central	1,680	6	36,200	5	1,760	6	38,000	5
West South Central	5,290	18	165,000	24	5,550	18	170,000	23
West:								
Mountain	1,210	4	22,700	3	1,280	4	26,000	3
Pacific	2,310	8	63,800	9	2,390	8	69,600	9
Total	29,700	100	685,000	100	30,600	100	752,000	100

W Withheld to avoid disclosing company proprietary data; included in "Middle Atlantic."
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 3
INDUSTRIAL SAND AND GRAVEL SOLD OR USED IN THE UNITED STATES, BY STATE[1]

(Thousand metric tons and thousand dollars)

State	2004		2005	
	Quantity	Value	Quantity	Value
Alabama	643	9,800	710	11,200
Arizona	W	792	W	W
Arkansas	W	W	W	W
California	1,990	55,700	2,030	60,400
Colorado	W	3,300	W	W
Florida	679	8,520	715	9,410
Georgia	665	13,400	689	15,000
Idaho	W	W	W	W
Illinois	4,950	86,200	5,510	104,000
Indiana	W	W	W	W
Iowa	W	W	W	W
Kansas	W	W	W	W
Louisiana	476	14,800	509	11,600
Maryland	W	W	W	W
Michigan	1,690	25,200	1,610	24,500
Minnesota	W	W	W	W
Mississippi	W	W	W	W
Missouri	589	14,200	559	14,500
Nebraska	W	W	--	--
Nevada	W	W	W	W
New Jersey	2,020	35,800	1,820	34,100
New Mexico	--	--	W	W
New York	W	W	--	--
North Carolina	1,630	29,000	1,150	29,200
North Dakota	W	W	W	W
Ohio	1,180	34,200	1,230	37,900
Oklahoma	1,390	31,600	1,480	33,500
Pennsylvania	570	11,800	711	15,400
Rhode Island	W	W	195	5,250
South Carolina	719	17,600	794	19,400
Tennessee	975	26,100	985	26,500
Texas	2,790	109,000	2,840	114,000
Virginia	W	W	W	W
Washington	W	W	W	W
West Virginia	343	17,300	369	17,800
Wisconsin	2,140	47,000	2,250	55,700
Other	4,300	93,300	4,380	112,000
Total	29,700	685,000	30,600	752,000

W Withheld to avoid disclosing company proprietary data; included in "Other." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 4
INDUSTRIAL SAND AND GRAVEL PRODUCTION IN THE UNITED STATES IN 2005, BY SIZE OF OPERATION[1]

Size range	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	20	16	259	1
25,000 to 49,999	9	7	303	1
50,000 to 99,999	21	17	1,390	5
100,000 to 199,999	25	20	3,140	10
200,000 to 299,999	10	8	2,210	7
300,000 to 399,999	9	7	2,860	9
400,000 to 499,999	3	2	1,200	4
500,000 to 599,999	6	4	2,970	10
600,000 to 699,999	4	3	2,330	8
700,000 and more	16	13	14,000	46
Total	123	100	30,600	100

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 5
NUMBER OF INDUSTRIAL SAND AND GRAVEL OPERATIONS AND PROCESSING PLANTS IN THE UNITED STATES IN 2005, BY GEOGRAPHIC DIVISION

	Mining operations on land					
Geographic region	Stationary	Portable	Stationary and portable	No plants or unspecified	Dredging operations	Total active operations
Northeast:						
New England	1	--	--	--	--	1
Middle Atlantic	5	--	--	--	3	8
Midwest:						
East North Central	25	--	--	--	3	28
West North Central	6	--	--	--	3	9
South:						
South Atlantic	18	1	--	--	6	25
East South Central	9	--	--	--	2	11
West South Central	17	--	--	--	5	22
West:						
Mountain	5	1	1	--	--	7
Pacific	12	--	--	--	--	12
Total	98	2	1	--	22	123

-- Zero.

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TABLE 6

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2005, BY MAJOR END USE[1]

Major use	Northeast			Midwest			South		
	Quantity (thousand metric tons)	Value (thousands)	Unit value[2] (dollars per ton)	Quantity (thousand metric tons)	Value (thousands)	Unit value[2] (dollars per ton)	Quantity (thousand metric tons)	Value (thousands)	Unit value[2] (dollars per ton)
Sand:									
Glassmaking:									
Containers	W	W	20.39	1,640	$19,700	12.02	1,680	$28,600	17.08
Flat, plate and window	W	W	19.07	844	12,500	14.85	1,510	27,100	18.01
Specialty	W	W	26.24	284	7,630	26.87	331	8,270	24.98
Fiberglass, unground	W	W	19.88	332	4,710	14.20	520	8,870	17.07
Fiberglass, ground	--	--	--	155	4,540	29.26	453	20,500	45.16
Foundry:									
Molding and core, unground	149	$4,620	30.98	4,400	70,200	15.93	737	13,200	17.92
Molding and core, ground	--	--	--	9	872	96.89	4	478	119.50
Refractory	(3)	9	30.95	8	711	88.88	96	2,210	23.03
Metallurgical:									
Silicon carbide	--	--	--	--	--	--	--	--	--
Flux for metal smelting	--	--	--	--	--	--	W	W	19.05
Abrasives:									
Blasting	55	1,910	34.73	78	3,210	41.18	655	17,200	26.25
Scouring cleansers, ground	(3)	1	70.82	W	W	97.50	W	W	44.62
Sawing and sanding	W	W	21.00	--	--	--	W	W	41.33
Chemicals, ground and unground	W	W	26.86	391	7,130	18.22	404	11,500	28.35
Fillers, ground, rubber, paints, putty, etc.	W	W	40.40	339	11,700	34.65	119	15,500	130.46
Whole grain fillers/building products	255	9,630	37.75	522	17,000	32.63	991	26,300	26.53
Ceramic, ground, pottery, brick, tile, etc.	W	W	82.80	33	2,120	64.30	120	6,800	56.68
Filtration:									
Water, municipal, county, local	53	1,790	33.81	57	2,690	47.23	154	6,300	40.91
Swimming pool, other	8	752	94.00	W	W	89.69	26	2,470	94.85
Petroleum industry:									
Hydraulic fracturing	(3)	2	41.45	2,740	110,000	40.19	1,250	63,100	50.53
Well packing and cementing	11	646	58.73	2	162	81.00	228	7,820	34.30
Recreational:									
Golf course, greens and traps	134	3,200	23.87	337	7,650	22.71	344	4,240	12.31
Baseball, volleyball, play sand, beaches	10	611	61.10	101	3,310	32.72	122	1,530	12.51
Traction, engine	20	469	23.45	60	1,160	19.35	69	1,270	18.42
Roofing granules and fillers	W	W	26.75	33	867	26.27	145	2,660	18.31
Other, ground silica	5	213	42.80	37	1,540	41.19	46	2,060	44.74
Other, whole grain	2,020	30,600	15.15	344	6,590	19.14	934	12,700	13.64
Total or average	2,720	54,400	20.02	12,800	296,000	23.23	10,900	291,000	26.60
Gravel:									
Silicon, ferrosilicon	--	--	--	W	W	7.08	W	W	15.31
Filtration	W	W	W	11	645	58.64	W	W	57.00
Nonmetallurgical flux	--	--	--	W	W	18.74	--	--	--
Other uses, specified	W	W	W	W	W	7.82	466	13,800	29.56
Total or average	4	374	93.50	99	1,330	13.45	466	13,800	29.56
Grand total or average	2,720	54,800	20.13	12,900	298,000	23.16	11,400	304,000	26.72

See footnotes at end of table.

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TABLE 6—Continued

INDUSTRIAL SAND AND GRAVEL SOLD OR USED BY U.S. PRODUCERS IN 2005, BY MAJOR END USE[1]

Major use	West			U.S. total		
	Quantity (thousand metric tons)	Value (thousands)	Unit value[2] (dollars per ton)	Quantity (thousand metric tons)	Value (thousands)	Unit value[2] (dollars per ton)
Sand:						
Glassmaking:						
Containers	W	W	22.37	4,950	$83,700	16.90
Flat, plate and window	W	W	22.19	3,130	56,200	17.97
Specialty	W	W	39.38	826	21,500	26.08
Fiberglass, unground	W	W	22.72	1,020	17,100	16.79
Fiberglass, ground	W	W	36.44	641	26,200	40.81
Foundry:						
Molding and core, unground	68	$1,760	25.91	5,360	89,700	16.75
Molding and core, ground	--	--	--	13	1,350	103.85
Refractory	--	--	--	104	2,930	28.18
Metallurgical:						
Silicon carbide	--	--	--	--	--	--
Flux for metal smelting	W	W	6.63	W	W	6.75
Abrasives:						
Blasting	119	6,180	51.96	908	28,500	31.38
Scouring cleansers, ground	--	--	--	W	W	47.96
Sawing and sanding	W	W	42.10	18	711	39.50
Chemicals, ground and unground	W	W	28.71	830	19,500	23.53
Fillers, ground, rubber, paints, putty, etc.	W	W	36.67	465	27,600	59.32
Whole grain fillers/building products	749	25,800	34.38	2,520	78,700	31.28
Ceramic, ground, pottery, brick, tile, etc.	W	W	27.76	208	10,500	50.30
Filtration:						
Water, municipal, county, local	112	6,470	57.79	375	17,300	46.02
Swimming pool, other	W	W	44.20	59	4,830	81.81
Petroleum industry:						
Hydraulic fracturing	W	W	47.47	4,010	174,000	43.45
Well packing and cementing	32	913	28.53	273	9,540	34.96
Recreational:						
Golf course, greens and traps	260	6,420	24.68	1,070	21,500	20.02
Baseball, volleyball, play sand, beaches	14	266	19.00	247	5,710	23.11
Traction, engine	12	361	30.08	161	3,260	20.26
Roofing granules and fillers	W	W	16.80	255	5,530	21.69
Other, ground silica	107	3,170	29.44	XX	XX	XX
Other, whole grain	1,810	40,200	22.23	XX	XX	XX
Total or average	3,280	91,500	27.90	29,700	733,000	24.69
Gravel:						
Silicon, ferrosilicon	--	--	--	343	5,150	15.02
Filtration	22	715	32.50	52	2,590	49.79
Nonmetallurgical flux	263	2,400	9.12	W	W	9.29
Other uses, specified	101	905	8.97	XX	XX	31.65
Total or average	386	4,020	10.41	955	19,500	20.42
Grand total or average	3,670	95,500	26.05	30,600	752,000	24.56

W Withheld to avoid disclosing company proprietary data; for sand, included in "Other, ground silica" or "Other, whole grain;" for gravel, included in "Other uses, specified." XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits except for unit values; may not add to totals shown.

[2]Calculated using unrounded data.

[3]Less then ½ unit.

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TABLE 7

INDUSTRIAL SAND AND GRAVEL SOLD OR USED, BY DESTINATION[1]

(Thousand metric tons)

Destination	2004	2005	Destination	2004	2005
States:			States—Continued:		
Alabama	657	623	New Jersey	1,460	1,490
Alaska	(2)	1	New Mexico	179	169
Arizona	68	55	New York	397	381
Arkansas	75	83	North Carolina	956	947
California	2,720	2,680	North Dakota	35	52
Colorado	651	848	Ohio	1,510	1,610
Connecticut	94	107	Oklahoma	815	952
Delaware	14	25	Oregon	63	82
District of Columbia	(2)	1	Pennsylvania	1,160	1,010
Florida	581	789	Rhode Island	50	60
Georgia	905	992	South Carolina	480	420
Hawaii	--	--	South Dakota	10	8
Idaho	399	320	Tennessee	881	819
Illinois	1,990	2,290	Texas	2,810	2,830
Indiana	940	1,190	Utah	46	42
Iowa	333	325	Vermont	3	3
Kansas	438	412	Virginia	330	342
Kentucky	295	300	Washington	206	212
Louisiana	540	557	West Virginia	137	156
Maine	2	(2)	Wisconsin	1,220	1,250
Maryland	93	101	Wyoming	154	170
Massachusetts	141	161	Countries:		
Michigan	980	997	Canada	848	821
Minnesota	296	338	Mexico	413	439
Mississippi	125	129	Other	44	51
Missouri	284	286	Other:		
Montana	48	23	Puerto Rico	(2)	(2)
Nebraska	38	21	U.S. possessions and territories	--	1
Nevada	42	109	Destination unknown	2,760	2,560
New Hampshire	3	2	Total	29,700	30,600

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

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TABLE 8

U.S. EXPORTS OF INDUSTRIAL SAND AND GRAVEL, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

Country	2004		2005	
	Quantity	Value[2]	Quantity	Value[2]
Africa and the Middle East:				
Oman	5	3,180	3	2,130
United Arab Emirates	1	995	2	548
Other	3	2,330	3	967
Total	9	6,500 r	8	3,640
Asia:				
China	18	8,730	17	14,600
Hong Kong	57	1,510	29	988
Japan	22	29,700	303	34,600
Korea, Republic of	3	1,820	4	2,450
Singapore	5	3,620	5	3,150
Taiwan	11	5,560	3	1,930
Other	4	1,540	2	1,120
Total	119 r	52,400 r	365	58,800
Europe:				
Belgium	4	4,000	4	1,950
Germany	10	15,000	40	19,200
Italy	(3)	81	5	335
Netherlands	14	11,600	11	9,340
Russia	19	11,700	5	4,390
United Kingdom	4	2,230	5	1,930
Other	17 r	17,500 r	2	2,380
Total	67	62,100	71	39,600
North America:				
Bahamas, The	7	249	(3)	34
Canada	1,240	33,900	2,130	32,000
Mexico	287	9,210	279	7,980
Trinidad and Tobago	1	191	2	337
Other	9 r	2,000 r	3	712
Total	1,540	45,600	2,410	41,000
Oceania:				
Australia	5	1,100	3	1,190
New Zealand	(3)	193	(3)	34
Total	5	1,290	3	1,220
South America:				
Argentina	30	4,490	35	5,970
Brazil	6	580	1	935
Colombia	2	286	2	344
Peru	2	227	6	897
Venezuela	2	464	3	1,050
Other	1 r	503 r	1	277
Total	43 r	6,550 r	49	9,480
Grand total	1,790	174,000	2,910	154,000

rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship value of material at U.S. port of export. Based on transaction price, includes all charges incurred in placing material alongside ship.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF INDUSTRIAL SAND, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

Country	2004		2005	
	Quantity	Value[2]	Quantity	Value[2]
Antigua and Barbuda	--	--	5	75
Australia	3	1,240	4	1,790
Canada	152	4,610	295	9,140
Chile	9	1,680	8	1,730
China	(3)	281	(3)	361
Germany	(3)	475	(3)	202
Japan	1	525	(3)	211
Mexico	300	2,830	382	4,080
New Zealand	2	232	--	--
Norway	21	84	15	63
Other	1 r	431 r	1	497
Total	490	12,400	711	18,200

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Cost, insurance, and freight value of material at U.S. port of entry. Based on purchase price; includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 10
U.S. PRODUCERS OF SPECIAL SILICA STONE PRODUCTS IN 2005

Company and location	Type of operation	Product
B&C Abrasives, Inc., Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Blue Mountain Whetstone Co., Hot Springs, AR	do.	Do.
Dan's Whetstone Co., Inc., Hot Springs, AR	do.	Do.
Do.	Quarry	Crude novaculite.
Hall's Arkansas Oilstones, Inc., Pearcy, AR	Stone cutting and finishing	Whetstones and oilstones.
Kraemer Co., The, Baraboo, WI	Crushing and sizing	Deburring media.
Do.	Quarry	Crude silica stone.
Norton Company Oilstones:		
Hot Springs, AR	do.	Do.
Littleton, NH	Stone cutting and finishing	Whetstones and oilstones.
Smith Abrasives, Inc., Hot Springs, AR	do.	Do.
Do.	Quarry	Crude novaculite.
Taylor Made Crafts Inc.:		
Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Pearcy, AR	Quarry	Crude novaculite.

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TABLE 11

INDUSTRIAL SAND AND GRAVEL (SILICA): WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Argentina	891	280	301 [r]	848 [r]	850
Australia[e]	4,500 [4]	4,500	4,500	4,500	4,000
Austria[e]	6,800	6,800	6,800	6,800	6,800
Belgium[e]	1,800	1,800	1,800	1,800	1,800
Belize	28	46	37	33	34
Bosnia and Herzegovina[e]	50	50	50	50	50
Brazil, silex[e]	1,600	1,600	1,600	1,600	1,600
Bulgaria[e]	900	900	900	900	900
Canada, quartz	1,613	1,540	1,581 [r]	1,690 [r]	1,600
Chile[e]	300	300	300	300	300
Croatia[e]	95	95	95	95	95
Cuba[e]	50	50	50	50	50
Czech Republic[e]	950	900	900	900	900
Denmark, sales[e]	50	55	60	60	60
Ecuador	35	41	39 [r]	43 [r]	43
Egypt[e, 5]	600	600	640	640	650
Eritrea	--	(6)	(6) [e]	(6) [e]	(6)
Estonia[e]	25	24	34	35	37
Ethiopia[e]	6 [e]	6 [e]	5 [r]	5 [r]	5
Finland[e]	148	148	112 [r]	100 [r]	100
France[e]	6,500	6,500	6,500	6,500	6,500
Gambia	170 [e]	1,508	1,534	1,530 [e]	1,530
Germany	7,835 [r]	7,839 [r]	7,953 [r]	8,162 [r]	8,160
Greece[e]	90	90	100	100	100
Guatemala	161	38	30	-- [r]	--
Hungary[e]	500	500	500	520	520
Iceland[e]	4	4	4	4	4
India[e]	1,400	1,400	1,500	1,500	1,600
Indonesia[e, 7]	128 [r]	128 [r]	132 [r]	132 [r]	132
Iran[8]	1,782 [r]	1,879 [r]	1,965 [r]	1,880 [r]	1,900
Ireland[e]	5	5	5	5	5
Israel	250 [r, e]	209 [r]	211 [r]	196 [r]	200
Italy[e]	3,000	3,000	3,000	3,000	3,000
Jamaica	8	9	13	11 [r]	11
Japan	5,768	4,893	4,700	4,705 [r]	4,750
Jordan[e]	90 [r]	60 [r]	33 [r, 4]	46 [r, 4]	46
Kenya[e]	12 [r]	12 [r]	13 [r]	13 [r]	13
Korea, Republic of	900	891	480	554 [r]	554
Latvia[e]	50	50	50	50	50
Lithuania[e]	30	30	30	30	30
Malaysia	575	447	534	631 [r]	620
Mexico	1,720	1,779	1,689	2,056 [r]	2,078 [4]
Netherlands[e]	5	5	5	5	5
New Caledonia[e]	40	40	40	40	40
New Zealand[e]	48	45	45	45	45
Norway[e]	1,500	1,400	1,500	1,500	1,600
Pakistan[e]	165	165	165	165	165
Paraguay[e]	28	25	26	25	25
Peru	120	300	196	871 [r]	900
Philippines[e]	70	70	70	70	70
Poland	1,564	1,486	1,500	1,500 [e]	1,500
Portugal[e]	5	5	5	5	5
Romania	733	1,569	3,061 [r]	1,458 [r]	1,500
Serbia and Montenegro[e]	75	75	75	75 [r]	100

See footnotes at end of table.

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TABLE 11—Continued

INDUSTRIAL SAND AND GRAVEL (SILICA): WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Slovakia	2,000	2,200	2,200	2,200 [e]	2,000
Slovenia	11,510	11,000	11,000 [e]	11,000 [e]	11,000
South Africa	2,127	2,239 [r]	2,448 [r]	2,388	2,754 [4]
Spain[e]	6,500	6,500	6,500	6,500	6,500
Sweden[e]	600	600	600	700 [r]	700
Thailand	514	781	1,294	588 [r]	590
Turkey	1,207	1,274	1,283	1,188 [r]	1,200
United Kingdom[e]	4,500	4,500	4,500	4,500	4,500
United States, sold or used by producers	27,900	27,300	27,500	29,700	30,600 [4]
Venezuela	627	690	700 [e]	700 [e]	750
Zimbabwe[9]	43	25	23	(6)	(6) [4]
Total	113,000 [r]	113,000	115,000 [r]	117,000 [r]	118,000

[e]Estimated. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through June 20, 2006.

[3]In addition to the countries listed, Angola, Antigua and Barbuda, The Bahamas, China, countries of the Commonwealth of Independent States, Iraq, and Saudi Arabia produce industrial sand, but current available information is inadequate to formulate reliable estimates of output levels.

[4]Reported figure.

[5]Fiscal years beginning July 1 of that stated.

[6]Less than ½ unit.

[7]The quantities for quartz sand and silica stone, in cubic meters, were as follows: 2001-02—145,000 (estimated) and 2003-05—150,000 (estimated).

[8]Fiscal years beginning March 21 of that stated.

[9]Includes rough and ground quartz as well as silica sand.

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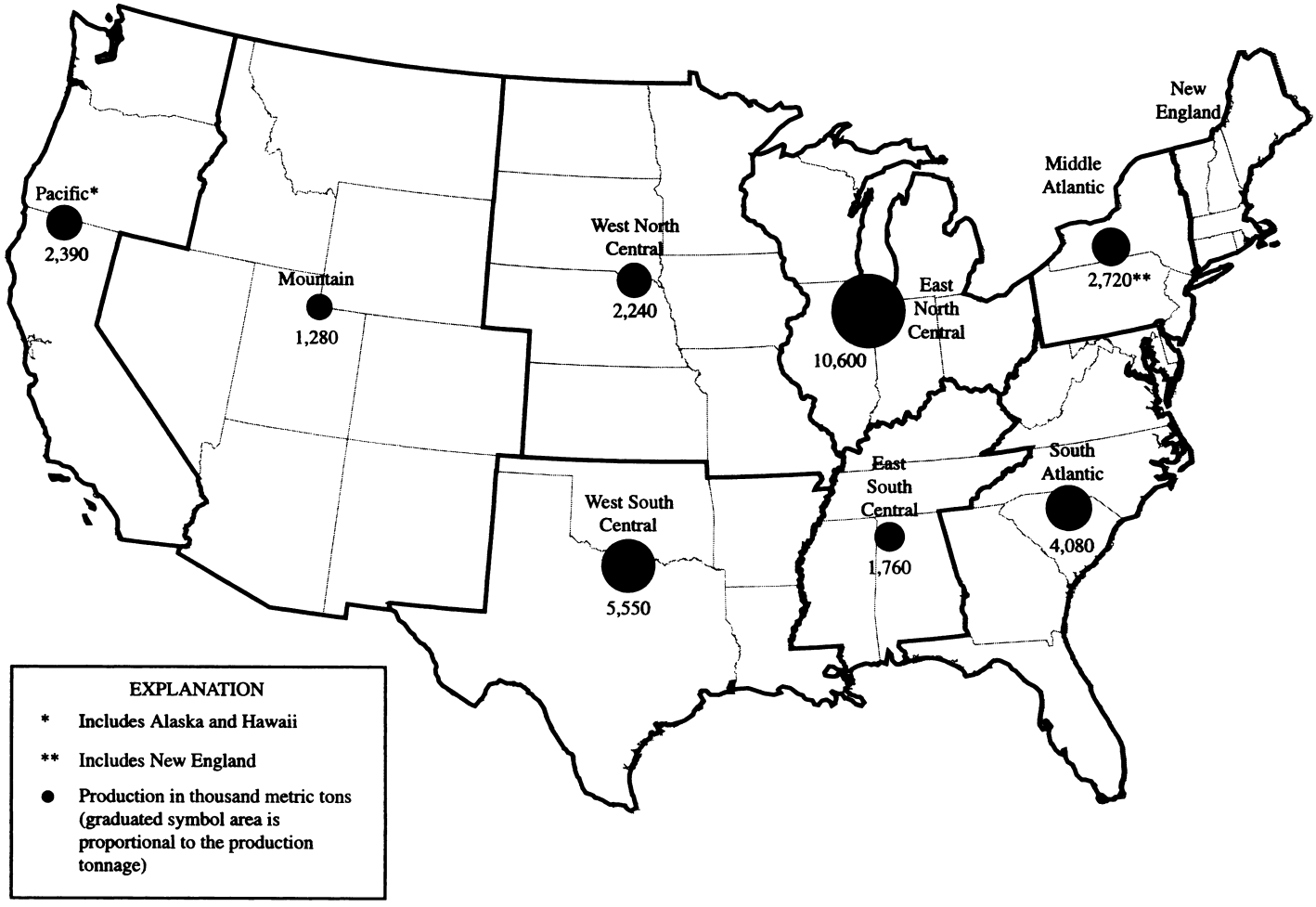
FIGURE 1
PRODUCTION OF INDUSTRIAL SAND AND GRAVEL IN THE UNITED STATES IN 2005, BY GEOGRAPHIC DIVISION



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SILICON

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In 2005, overall domestic silicon production decreased from that of 2004. At 270,000 metric tons (t) of contained silicon, production was 2% lower than that of 2004 (table 1). On a gross-weight basis, production decreased by 1% from that in 2004 (table 2). On the basis of contained silicon, U.S. exports of silicon products increased by 24%, and imports increased by 4%. The increase in exports was associated with increases in the "more than 55% silicon" ferrosilicon and "more than 99.99% silicon" and "other" silicon metal trade categories (table 5). The increase in imports was primarily attributable to increases in the "55% to 80% silicon" ferrosilicon and the "other" ferrosilicon metal trade categories (table 6). Apparent consumption for ferrosilicon increased by 7% and for silicon metal decreased by 5% compared with that in 2004 (revised). Year-average import prices for silicon metal decreased by 7%, and those for the 50% and 75% ferrosilicon grades decreased by 5% and 13%, respectively, compared with those in 2004 (table 1).

Silicon is a light chemical element with metallic and nonmetallic characteristics. Silicon is not found free in nature. Silicon combines with oxygen and other elements to form silicates, which comprise more than 25% of the Earth's crust. Silica (SiO_2) as quartz or quartzite is used to produce silicon ferroalloys for the iron and steel industries and silicon metal for the aluminum and chemical industries. Silicon metal that is refined into semiconductor-grade metal for use in making computer chips is crucial to modern technology, but the quantity is less than 5% of total silicon metal demand (Roskill's Letter from Japan, 2000). Silicon metal may also be refined into wafers used to power solar batteries. The U.S. Geological Survey (USGS) does not survey the high-purity silicon industry for production and related data; therefore, the only information that this report contains about these high-purity grades is as it appears in the foreign trade statistics and from published sources.

Legislation and Government Programs

The General and Plastic Surgery Devices Advisory Panel for the U.S. Food and Drug Administration (FDA) met April 11-13 to give advice and recommendations to the FDA on the premarket approval applications for silicone-filled breast implants submitted by Inamed Corporation and Mentor Corporation. After reviewing company data and FDA and public comments, the panel voted five to four against approving Inamed's application and seven to two in favor of approving Mentor's application with conditions. In the case of Inamed, the panel felt the performance of the implant device was inadequate and that additional patient followup data were needed (U.S. Food and Drug Administration, 2005§[1]).

Production

Silicon Ferroalloys[2] and Metal.—Domestic production data for silicon are derived from monthly and annual voluntary surveys and estimates for nonrespondents by the USGS. The data in table 2 were obtained from all operations listed in table 3 that are canvassed by means of the USGS "Silicon Alloys" survey. In terms of gross weight and compared with those of 2004, overall domestic gross production, net shipments, and stocks of silicon products decreased by 1%, 2%, and 15%, respectively. The most pronounced year-to-year changes were in the 75% ferrosilicon category, for which production and shipments decreased by 7% and 4%, respectively. Production of 50% ferrosilicon increased by 2%, and shipments and stocks decreased by 2% and 12%, respectively. Data for ferrosilicon reflected adjustments in inventory and in-plant consumption of ferrosilicon to produce magnesium ferrosilicon and other miscellaneous alloys. Silicon metal production and shipments both fell by 1% (table 2).

Elkem ASA (a subsidiary of Orkla ASA) announced late in the year that it would sell its silicon plant and associated hydroelectric plant located in Alloy, WV, to U.S. ferroalloys producer Globe Metallurgical, Inc. for $130 million (Orkla ASA, 2005§). The sale would double Globe's silicon metal production capacity to 135,000 metric tons per year (t/yr) from 65,000 t/yr and would make the company the leading U.S. silicon metal producer (Ryan's Notes, 2005a). The sale would also reduce the number of companies that produce silicon metal in the United States to two from three.

Semiconductor- and Solar-Battery-Grade Silicon.—U.S. production of polycrystalline silicon used in semiconductor-grade silicon was reported to be 10,100 t in 2005; solar-battery-grade production was 5,400 t. Total domestic polycrystalline production capacity in 2005 was 16,800 t, as follows: Hemlock Semiconductor Corporation, 7,700 t; REC Advanced Silicon Materials LLC, 3,000 t; MEMC Electronic Materials, 2,700 t; REC Solar Grade Silicon LLC, 2,200 t; and Mitsubishi Materials Group, 1,200 t (Roskill's Letters from Japan, 2006).

Consumption

Silicon Ferroalloys and Metal.—The majority of ferrosilicon (including miscellaneous silicon alloys) was used to produce steel (65%) and cast irons (32%) (table 4). Silicon metal was used mainly to produce chemicals—silanes, silicones, and others—and silica fume (76%). Metallurgical-grade silicon carbide can substitute for ferrosilicon, especially in iron foundries. Data on North American production and U.S. imports of silicon carbide are reported in the Manufactured Abrasives

[1]References that include a section mark (§) are found in the Internet References Cited section.

[2]There are two standard grades of ferrosilicon—50% and 75%. A more detailed explanation of these grades is found in table 2.

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chapter of the 2005 USGS Minerals Yearbook, volume I, Metals and Minerals.

Total U.S. apparent consumption of silicon ferroalloys and metal in 2005 increased by 1% to 592,000 t from the revised estimate of 588,000 t in 2004 (contained silicon). Apparent consumption increased by 7% to 317,000 t for ferrosilicon and miscellaneous silicon alloys and decreased by 5% to 275,000 t for silicon metal. Increases in net imports for consumption contributed to the rise in ferrosilicon apparent consumption. Decreases in net imports for consumption led to the decline in silicon metal apparent consumption. Ferrosilicon and miscellaneous silicon alloys accounted for 54% of the total demand.

The ratio of reported to apparent consumption on a content basis was 66:34 for ferrosilicon, which includes miscellaneous silicon alloys, and 85:15 for silicon metal. These ratios were derived based on the typical silicon content of the materials noted in table 4.

Consumption of ferrosilicon and silicon metal was estimated by CRU International Ltd. to have decreased in 2005 throughout the Western World. In terms of contained silicon, ferrosilicon consumption decreased to 1.97 million metric tons (Mt) from 2.08 Mt (revised) in 2004, and silicon metal consumption decreased to about 1.28 Mt from 1.29 Mt. Areas with the largest year-to-year decrease in consumption were, for ferrosilicon, Japan, Europe, and Asian countries (excluding China, Japan, and North Korea), and for silicon metal, Japan and the United States. In decreasing order of consumption, Europe, Japan, and other Asian countries accounted for 70% of the ferrosilicon consumption in 2005. Also in decreasing order of consumption, Western Europe, the United States, and Japan accounted for 77% of the silicon metal consumed in 2005 (CRU Bulk Ferroalloys Monitor, 2006a, b).

Semiconductor- and Solar-Battery-Grade Silicon.—Global demand for silicon wafers made from polycrystalline silicon increased by 6% as shipments rose to 6,640 million square inches from 6,260 million square inches in 2004. The value of the shipments increased by 8% to $7.9 billion from $7.3 billion in 2004 (Roskill's Letters from Japan, 2006).

Prices

Ferrosilicon and silicon metal prices (excluding those of high-purity silicon) tend to vary in response to changes in demand and supply by the steel, ferrous foundry, aluminum, and chemical industries. Year-average import prices given by Platts Metals Week were 48.0 cents per pound for 75% ferrosilicon and 76.2 cents per pound for silicon metal; these prices were 13% and 7% lower, respectively, than those of 2004. The year-average North American transaction price for 50% ferrosilicon as calculated from Ryan's Notes listings was 55.0 cents per pound, a 5% decrease from that of 2004. Prices for both standard grades of ferrosilicon fell based on decreased crude steel production and higher import levels from those of 2004 (Metal Bulletin Ferro-Alloys Monthly, 2005a). Lower silicon metal prices in the United States were attributed to a decrease in demand by the secondary aluminum sector (Metal Bulletin Ferro-Alloys Monthly, 2005b).

Annual polycrystalline contract prices were estimated to be $50 to $55 per kilogram for semiconductor-grade silicon and $40 to $45 per kilogram for solar-battery-grade material (Roskill's Letters from Japan, 2006).

Foreign Trade

Trade volumes discussed below are based on gross weight. U.S. ferrosilicon exports increased by 17% to 23,400 t, and their value increased by 15% to $13.4 million from that of 2004. In decreasing order of quantity, Canada and Mexico accounted for 97% of the total 2005 ferrosilicon exports (table 5). Exports of silicon metal increased by 25%, and their value increased by 73% to $847 million from that of 2004. In decreasing order of quantity, Japan, Canada, and China accounted for 57% of silicon metal exports. Shipments of high-purity silicon containing more than 99.99% silicon accounted for 63% of total silicon metal exported and 96% of the total value of combined ferrosilicon and silicon metal exports.

U.S. ferrosilicon imports increased by 17% to 290,000 t, but increased in value only by 7% to $215 million compared with that in 2004. The rise in ferrosilicon imports was primarily attributable to increases in the "55% to 80%, other" and "other" ferrosilicon trade categories. Imports of standard 75% ferrosilicon (ferrosilicon category of "55% to 80% silicon, other") accounted for 81% of total ferrosilicon imports by gross weight and value (table 6). China was the leading source of ferrosilicon imports at 45%, followed by Venezuela at 16%.

Silicon metal imports decreased by 6% to 157,000 t from 167,000 t in 2004, but increased by 17% in value to $366 million from $314 million. Imports fell because of decreases in the "99.00% to 99.99% silicon" category. Brazil was the leading source of the "99.00% to 99.99% silicon" import category at 42%, followed by South Africa at 28%. This category accounted for 51% of the total value for silicon metal imports and showed an increase of 8% from that in 2004.

The estimated U.S. net import reliance for ferrosilicon in 2005 increased to 61% from 57% in 2004 (revised), and that for silicon metal decreased to 47% from 50%. The overall import reliance for silicon was estimated to be 54%, about the same as that of the revised level (53%) in 2004.

The general rates of duty that applied to U.S. imports during 2005 were the same as in 2004. These were, on an ad valorem basis, 5.8% for ferrosilicon containing more than 90% silicon; 5.3% or 5.5% for metal exclusive of the high-purity grade, which is free; 1.9% for ferrosilicon containing 80% to 90% silicon; 1.5% for standard 75% ferrosilicon; 1.1% for nominal 75% ferrosilicon that contains more than 3% calcium; and free for magnesium ferrosilicon and other ferrosilicon (U.S. International Trade Commission, 2006).

Silicon Metal Imports from Brazil (July 1, 1998, through June 30, 1999).—On October 6, the U.S. Court of International Trade (CIT) affirmed the revised antidumping duty margins for silicon metal imports from Companhia Brasileira Carbureto de Calcio (CBCC) and Eletrosilex, S.A., which were zero and 61.58%, respectively, that were calculated by the International Trade Administration (ITA) of the U.S. Department of Commerce on July 14, 2004 (Elkem Metals Company v. United

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States, Consol. Court No. 01-00098, CIT Slip Opinion 05-134). Although the CIT agreed with the revised duties, the ITA suspended liquidation of the imports until a conclusive decision[3] could be made in the case (International Trade Administration, 2005e).

Silicon Metal Imports from Russia (July 2001 through December 2001).—On January 5, upon remand by the CIT, the ITA recalculated the dumping margin rates for silicon metal imported from Russia by Bratsk Aluminum Smelter to 87.08% from 79.42%, and by ZAO Kremny/Sual-Kremny-Ural Ltd. (ZAO Kremny) to 56.2% from 56.11% . On July 25, the CIT affirmed the revised antidumping duty margin rate for Bratsk, but remanded that of ZAO Kremny back to the ITA for further evaluation (Globe Metallurgical Inc. v. United States, Consol. Court No. 03-00202, CIT Slip Opinion 05-90). The ITA submitted its revised antidumping duty rate of 61.61% for ZAO Kremny on October 25, which the CIT affirmed on November 28 (Globe Metallurgical Inc. v. United States, Consol. Court No. 03-00202, CIT Slip Opinion 05-150) (Platts Metals Week, 2005). Although the CIT agreed with the revised duties, the ITA suspended liquidation of the imports until a conclusive decision could be made in the case (International Trade Administration, 2005b).

Silicon Metal Imports from Brazil (July 1, 1999, through June 30, 2000).—On August 26, the CIT upheld the 0.48% duty margin rate on silicon metal imported from Brazil by Rima Industrial S.A. that the ITA had recalculated on remand on March 16 (Elkem Metals Company v. United States, Consol. Court No. 02-00232, CIT Slip Opinion 05-109). Although the CIT agreed with the revised duty, the ITA suspended liquidation of the imports until a conclusive decision could be made in the case (International Trade Administration, 2005d).

Pending U.S.-Southern African Customs Union Free Trade Agreement.—Representatives from the Office of the United States Trade Representative (USTR) and member nations of the Southern African Customs Union (Botswana, Lesotho, Namibia, South Africa, and Swaziland) continued negotiations on the pending U.S.-Southern African Customs Union Free Trade Agreement (FTA). In April 2006, the parties agreed to establish a framework for pursuing the FTA over the longer term (Office of the United States Trade Representative, 2006§). The USTR launched negotiations for the FTA on June 2, 2003 (Office of the United States Trade Representative, 2003§). The FTA could result in the elimination of the 5.5% ad valorem duty on imports of less than 99.00% silicon metal from South Africa.

Antidumping Duty Administrative Reviews.—On August 8, the ITA preliminarily determined that Brazilian producer Camargo Correa Metais, S.A. (CCM) did not sell silicon metal at less than the normal value during the period of July 1, 2003, through June 30, 2004 (International Trade Administration, 2005g). In late November, the ITA extended the deadline for making a final determination until February 4, 2006 (International Trade Administration, 2005c).

The ITA also began an antidumping duty administrative review of silicon metal imports during the period of July 1, 2004, through June 30, 2005, from Brazilian producers CCM, Companhia Ferroligas de Minas Gerais-Minasligas (Minasligas), and Ligas de Aluminio S.A. (LIASA) on August 29 (International Trade Administration, 2005a). On November 28, the ITA rescinded the administrative review for the companies because none had sales or exports of the subject merchandise during the period of review (International Trade Administration, 2005f).

[3]The ITA determines a "conclusive" decision is made when either a trade case is not appealed or it is affirmed by the Court of Appeals for the Federal Circuit on appeal. When such a decision is reached, the ITA will instruct the U.S. Customs and Border Protection to liquidate the subject merchandise.

World Review

Data on annual world production of ferrosilicon and silicon metal by country during 2001 through 2005 are provided in the Ferroalloys chapter of the 2005 USGS Minerals Yearbook, volume I, Metals and Minerals. World production of ferrosilicon was estimated to have been 5.43 Mt in 2005 compared with 5.66 Mt (revised) in 2004. The major ferrosilicon producers in 2005 were, in decreasing order, China, Russia, Norway, Ukraine, the United States, Brazil, South Africa, Iceland, and Kazakhstan; they accounted for 87% of total production as listed in table 1. World production of silicon metal, excluding that from China, was estimated to have been 662,000 t in 2005 compared with 658,000 t (revised) in 2004. Firm data on China's production of silicon metal are lacking, although one source reported it to be 520,000 t/yr (Ryan's Notes, 2004). At this rate, China is by far the leading producer of silicon metal in the world. Other major producers of silicon metal in 2005 were, in decreasing order, the United States, Brazil, Norway, France, South Africa, and Russia; they accounted for about 84% of total production as listed in table 1.

Bhutan.—Bhutan Ferro Alloys Limited reported that it had the capacity to produce ferrosilicon (about 21,000 t/yr), silica fume (4,200 t/yr), and magnesium ferrosilicon (2,400 t/yr). The company also mentioned it would be commissioning a new 18-megavoltampere (MVA) furnace for silicon and manganese alloys by yearend (Bhutan Ferro Alloys Limited, 2006§). The new furnace would have the capacity to produce about 12,000 t/yr of ferrosilicon (Metal-Pages, 2005a§).

Bosnia and Herzegovina.—In May 2004, Italian ferroalloy producer Metalleghe Spa acquired the Elecktrobosma silicon plant located in Jajce, Bosnia. The plant has three 7.5 megawatt furnaces with a combined capacity of about 15,000 t/yr. Most of the silicon metal produced at the plant is sold in Italy (Ryan's Notes, 2005d).

China.—China's exports of ferrosilicon containing more than 55% silicon rose slightly to an alltime high of 916,911 t from that of 2004, and those containing 55% or less silicon increased by 6% to 24,094 t. China exported 536,130 t of silicon metal in 2005, a decrease of 2% from 545,034 t in 2004 (TEX Report, 2006a, b).

To reduce ferroalloy and metal exports, China's Ministry of Finance revoked the 8% export tax rebate on ferrosilicon starting January 1. On April 29, the Government also repealed the 13% export tax rebate on silicon metal effective May 1, 2005, and imposed a 5% export tax on ferrosilicon effective June 1, 2005 (TEX Report, 2005a, b).

The Central Government of China, through the National Development and Reform Commission (NDRC), estimated

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the number of ferroalloy producers in the country to be 1,570; total installed production capacity was about 22 million metric tons per year (Mt/yr) (twice that of 2000). In 2005, 1.16 Mt of ferroalloy capacity was under construction, with an additional 1.23 Mt planned. Ferroalloy production during the year was 10.67 Mt, and the amounts consumed, exported, and imported were 9.30 Mt, 1.74 Mt, and 370,000 t, respectively. China accounted for 40% of global ferroalloy production and 30% each of global consumption and exports (TEX Report, 2006d, f).

Because of overcapacity, the NRDC issued a bulletin on July 5 that established a national system for approving state-owned ferroalloy companies. The new system would also reduce energy consumption and increase environmental protection by the ferroalloys industry. The NDRC also set a limit for energy consumption at 8,500 kilowatts per metric ton of 75% ferrosilicon produced (TEX Report, 2005b, c).

As part of the approval process, state-owned ferroalloy producers were required to report the following information: total capital, profit, number of production facilities, the amount of energy consumed, and environmental protection controls at plant operations. Plant inspections would be conducted to verify compliance with regulations instituted in 2004 as described in the Silicon chapter of the 2004 Minerals Yearbook, volume I, Metals and Minerals. The NDRC announced the names of 25 ferrosilicon and 3 silicon metal producers that met environmental standards as of December 31 (TEX Report, 2006d, e).

France.—On April 5, Spanish ferroalloy producer Ferroatlantica S.L. purchased Pechiney Électrométallurgie (PEM) from Alcan Inc. for €140 million ($180 million) (Yahoo!Finance France, 2005§). The sale was completed by June (Alcan Inc., 2005§). PEM's ferroalloy division includes ferrosilicon and silicon metal producer Invesil with four plants in France and one in South Africa.

Japan.—The Japanese aluminum industry consumed 63,205 t of silicon metal, a 4% increase compared with that in 2004 because of greater demand by the automotive manufacturing sector (TEX Report, 2006h). The Japanese steel industry consumed 383,182 t of ferrosilicon, a 3% increase from that in 2004 (TEX Report, 2006g). Ferrosilicon imports containing at least 55% silicon were 466,364 t at an annual average price of $743.70 per metric ton, down from 538,668 t at $816.97 per ton in 2004. Other ferrosilicon imports were 20,324 t at an average annual price of $769.26 per ton, down from 24,172 t at $787.23 per ton. Silicon metal imports were 222,851 t at an annual average price of $1,204.35 per ton, down from 242,439 t at $1,221.18 per ton in 2004 (TEX Report, 2006c).

Mexico.—Hascor Metals S.A. de C.V. started full production of magnesium ferrosilicon at a rate of 200 to 250 metric tons per month at its plant in Tamos, Tampico (Ryan's Notes, 2005e).

Norway.—In March, Alcoa Inc. agreed to sell its 46.5% stake in silicon producer Elkem to Orkla for $870 million. With this sale, Orkla acquired about 98% ownership in Elkem (Alcoa Inc., 2005§). In April, Orkla made an offer for the remaining Elkem shares (American Metal Market, 2005§). Elkem's ownership in Norwegian-based Renewable Energy Corporation AS (REC) increased to 27.5% from 25% in 2004. REC produces silicon raw materials and wafers for the solar cell industry (Elkem ASA, 2006a§). In January 2006, Elkem announced it would close its silicon metal plant in Meraker, Norway, by midyear 2006 in response to tougher international competition (particularly from China) (Elkem ASA, 2006b§).

Fesil ASA reported that its Lilleby Metall ferrosilicon and silicon metal plant remained shut down during 2005, although necessary maintenance was performed for a possible future restart (Fesil ASA, 2006§).

Finnfjord Smelteverk ASA closed its Finnsnes, Norway, ferrosilicon plant indefinitely in October. The plant has an operating capacity of 100,000 t/yr (Ryan's Notes, 2005b).

Russia.—Chelyabinsk Electrometallurgical Integrated Plant planned to produce 600,000 t of ferrosilicon containing 45% silicon during 2005 (TEX Report, 2005d). The company's ferroalloy production mix was about 39% ferrosilicon, 25.5% ferrochrome, 19.6% silicomanganese, and 13.5% ferrochromium silicon (Interfax Metals & Mining Weekly, 2006a).

Kuznetsk Ferroalloy Works (KFZ) increased production of ferrosilicon containing 45% silicon by 11% to 439,922 t during 2005. KFZ also raised production of microsilica (fume silica) by 4% to 15,528 t. KFZ invested Rub195 million (approximately $6.79 million) in 2005 to construct a new ferrosilicon line at the former Yurga abrasives plant in the Kemerovo region of Russia; production was expected to start in May 2006 (Interfax Metals & Mining Weekly, 2006b). Production capacity at the Yurga plant was planned to be up to 70,000 t/yr of 75% ferrosilicon (Interfax Mining & Metals Report, 2004).

Taiwan.—Taiwan imported 73,653 t of standard ferrosilicon (more than 55% silicon content) during 2005, a 17% decrease from that of 2004. Of that amount, 76% came from China, 14% from Russia, and 6% from Brazil (TEX Report, 2006i).

Ukraine.—SUAL Group acquired 69% ownership in Zaporozhye Aluminum Combine in 2004 (Ryan's Notes, 2005c). Stakhanov Ferroalloy Plant, the country's sole ferrosilicon producer, announced plans to invest about $16 million in plant improvements during 2005. Capital expenditures would include the continued reconstruction of its furnaces and installation of a new gas purification system (Metal-Pages, 2005b§).

Current Research and Technology

Metal Powder.—Metalysis Ltd., United Kingdom, used the Fray-Farthing-Chen (FFC) Cambridge process to produce silicon metal powder directly from silicon oxide powder. The FFC Cambridge process uses a molten salt to electrolytically extract silicon from the metal powder. Other metals can also be produced this way. The company believes there is potential to produce metal alloys directly from mixed metal oxides without the need for smelting (Metalysis Ltd., 2005§).

Nanotechnology.—NanoDynamics, Inc., Buffalo, NY, developed a new high-rate, low-cost method for anisotropically etching silicon wafers by an electrochemical process. The new process yields more silicon wafers than traditional processes; a higher yield would reduce the overall cost of fuel cells. The new wafers might also increase energy efficiency, thereby reducing the fuel-cell size (larger cells and more fuel are required for less efficient fuel cells) (Advanced Materials & Processes, 2005).

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Silicon Chemicals.—GE Advanced Materials (a consolidated affiliate of General Electric Company) announced two new silanes, the NXT LowV™ and NXT Ultra-LowV™, for use in the production of silica-base tire tread compounds. The new products can be made in one step rather than the multistep process required to mix silica with rubber when using traditional polysulfide silanes. The new materials can also lower ethanol emissions by up to 90% because they do not react with rubber like traditional polysulfide silanes do. While silica tires help reduce automobile fuel consumption by up to 5% and improve traction and handling, they have been difficult to manufacture (GE Advanced Materials, 2005b§). GE Advanced Materials also introduced its Silbreak™ line of silicone demulsifiers for crude oil separation. Silbreak™ may allow the development of crude oil resources currently considered "economically unattractive" (GE Advanced Materials, 2005a§).

Researchers at the University of Wisconsin-Madison developed a new type of rechargeable lithium battery that could last up to 12 years. The battery uses current lithium battery technology, except it contains an organosilicon electrolyte. The new batteries will be used in medical implants, such as muscle stimulators used to help patients with Parkinson's disease (Batteries Digest, 2005§).

Silicon in Computer Chips.—Researchers from the University of Illinois fabricated extra-thin ribbons of silicon that can expand and crumple like an accordion's bellows. Unlike silicon on conventional chips, this new form of silicon can flex, bend, and even conform to curved objects like airplane wings and robotic limbs. Flexible silicon could be used in conformal electronics and devices as well as lead to new types of sensors and environmentally sensitive processors (Chemical & Engineering News, 2005).

Scientists at Intel Corporation's Photonics Technology Lab reported the development of a silicon laser that emits a continuous instead of a pulsed beam. As computer processing speeds increase, they are nearing the physical limits of copper to carry more information. Getting silicon to emit a continuous stream of light could resolve this issue by increasing the flow of data transmitted in computers (Savage, 2005).

Outlook

Demand for ferrosilicon follows trends in the iron and steel industries, for which the combined annual growth rates (CAGRs) have been typically in the range of 1% to 2% in the United States. Details of the outlook for the steel industry are discussed in the Outlook section of the Iron and Steel chapter of the 2005 USGS Minerals Yearbook, volume I, Metals and Minerals. Raw steel production decreased by 6% in the United States while increasing 7% globally from that in 2004. World apparent consumption of finished steel products increased by 4.1% to 1.013 billion metric tons (Gt) in 2005 from that in 2004 (International Iron and Steel Institute, 2006§). This increase was primarily attributed to steel consumption in Asia, particularly in China. Asia accounted for 55% of steel consumed worldwide in 2005, up by 10.1% to 554.9 Mt from that in 2004. China alone consumed 315 Mt, a 16.7% increase from 2004. Steel consumption in 2005 was also up in Africa, the Commonwealth of Independent States, and the Middle East.

Demand for silicon metal comes primarily from the aluminum and chemical industries. The American Chemistry Council estimated a slight (0.2%) drop in domestic chemical output in 2005, primarily as a result of damage caused to chemical plants along the Gulf Coast by Hurricanes Katrina and Rita (Storck, 2006, p. 12-15). Demand for silicon by the U.S. aluminum castings industry was expected to mirror the 2.7% increase in aluminum casting shipments forecast for 2006 and to rise by 8.3% and 1.6% by 2008 and 2015, respectively (Kirgin, 2006§).

World production of polycrystalline silicon can be used as a rough indicator of high-purity silicon demand. Compared with that of 2004, world production of polycrystalline silicon was forecast to increase by 8% to 29,100 t in 2005, by 20% to 32,500 t in 2006, and by 46% to 39,500 t in 2007 (Roskill's Letter from Japan, 2006, p. 7).

Demand for microsilica comes from the cement industry. Domestic demand for cement through 2009 was forecast to increase by 2.5% from 120 Mt in 2005 (International Cement Review, 2006). Worldwide demand for cement was projected to rise by 4.1% per year through 2006 to 2.1 Gt, although advances were expected to be less robust in more developed areas, such as Japan, the United States, and Western Europe (Mining Engineering, 2002).

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TABLE 1
SALIENT SILICON STATISTICS[1]

		2001	2002	2003	2004	2005
United States production, si content:						
Ferrosilicon	thousand metric tons	148	150	116	128	125
Silicon metal	do.	134	111	137	147	145
Exports:						
Ferrosilicon	do.	10	7	6	6	8
Silicon metal	do.	12	15	20	18	23
Imports for consumption:						
Ferrosilicon	do.	115	140	189	173	197
Silicon metal	do.	116	145	126	165	152
Apparent consumption:						
Ferrosilicon	do.	258	301	304	297 r	317
Silicon metal	do.	244	240	240	291 r	275
Price, average:						
Ferrosilicon, 50% Si[2]	cents per pound	42.80	41.10	47.70	58.20	55.00
Ferrosilicon, 75% Si[3]	do.	31.90	32.90	45.30	55.40	48.00
Silicon metal[4]	do.	50.50	53.20	61.30	81.90	76.20
World production, gross weight:						
Ferrosilicon	thousand metric tons	4,040 r	4,230 r	4,950 r	5,660 r	5,430
Silicon metal[5]	do.	603 r	610 r	641 r	658 r	662

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits.

[2]Ryan's Notes North American transaction prices based on weekly averages.

[3]Platts Metals Week mean import prices based on monthly averages.

[4]Platts Metals Week dealer import prices based on monthly averages.

[5]Excluding China.

TABLE 2
PRODUCTION, SHIPMENTS, AND STOCKS OF SILICON ALLOYS AND METAL IN THE UNITED STATES[1, 2]

(Metric tons)

Material	Silicon content (percent)		2004 producers' stocks, December 31 gross weight	2005		
	Range	Typical		Gross production[3] gross weight	Net shipments gross weight	Producers' stocks, December 31 gross weight
Ferrosilicon[4]	25-65 [5]	48	10,400	123,000	86,200	9,130
Do.	56-95	76	13,100	86,100	89,500	10,800
Silicon metal, excluding semiconductor grades	96-99	98	7,530	148,000	140,000	6,380

[1]Data are rounded to no more than three significant digits.

[2]Data for silvery pig iron (less than 25% silicon) withheld to avoid disclosing company proprietary data.

[3]Ferrosilicon production includes material consumed in the production of miscellaneous silicon alloys.

[4]Includes miscellaneous silicon alloys, which were listed separately prior to 1999.

[5]25% to 55% for ferrosilicon; 32% to 65% for miscellaneous silicon alloys.

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TABLE 3
PRINCIPAL PRODUCERS OF SILICON ALLOYS AND/OR SILICON METAL IN THE UNITED STATES IN 2005

Producer	Plant location	Product
CC Metals and Alloys, Inc.	Calvert City, KY	Ferrosilicon.
Elkem Metals Co.	Alloy, WV	Ferrosilicon and Silicon metal.
Globe Metallurgical, Inc.[1]	Beverly, OH	Do.
Do.	Selma, AL	Silicon metal.
Oxbow Carbon and Minerals LLC	Bridgeport, AL	Ferrosilicon.
Simcala, Inc.	Mt. Meigs, AL	Silicon metal.

[1]Globe also had a silicon ferroalloys plant in Niagara Falls, NY, but it was idle in 2005.

TABLE 4
REPORTED CONSUMPTION, BY END USE, AND STOCKS OF SILICON FERROALLOYS AND METAL IN THE UNITED STATES IN 2005[1, 2]

(Metric tons, gross weight)

End use	Silvery pig iron[3]	Ferrosilicon, 50%[4]	Ferrosilicon, 75%[5]	Silicon metal[6]	Miscellaneous silicon alloys[7]	Silicon carbide[8]
Steel:						
Carbon and high-strength, low-alloy	--	(9)	17,700	(10)	1,270	(9)
Stainless and heat-resisting	--	(9)	48,100	282	(9)	2,600
Full alloy	--	(9)	7,430	(10)	(9)	--
Electric and tool	--	--	29,800	--	(9)	(9)
Unspecified	--	31,100	(10)	(10)	588	4,900
Total	--	31,100	103,000	282	1,850	7,500
Cast irons	3,720	29,000	27,100	(10)	11,300	25,600
Superalloys	--	(11)	(10)	279	--	--
Alloys, excluding superalloys and alloy steel	(11)	3,920	(10)	55,400 [12]	--	--
Miscellaneous and unspecified	--	--	1,350	178,000 [13]	(11)	--
Grand total	3,720	64,000	132,000	234,000	13,200	33,100
Consumers' stocks, December 31	332	2,960	9,060	1,830	697	1,420

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes U.S. Geological Survey estimates.

[3]Typically 18% silicon content but ranges between 5% to 24% silicon content.

[4]Typically 48% silicon content but ranges between 25% to 55% silicon content; includes briquets.

[5]Typically 76% silicon content but ranges between 56% to 95% silicon content; includes briquets.

[6]Typically 98% silicon content but ranges between 96% to 99% silicon content.

[7]Typically 48% silicon content. Primarily magnesium-ferrosilicon but also includes other silicon alloys.

[8]Typically 64% silicon content but ranges between 63% to 70% silicon content. Does not include silicon carbide for abrasive or refractory uses.

[9]Included with "Steel: Unspecified," to avoid disclosing company proprietary data.

[10]Included with "Miscellaneous and unspecified," to avoid disclosing company proprietary data.

[11]Included with "Cast irons," to avoid disclosing company proprietary data.

[12]Primarily aluminum alloys.

[13]Primarily silicones, silanes, fumed silica, and other chemicals.

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TABLE 5

U.S. EXPORTS OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 2005[1]

Country	Gross weight (metric tons)	Contained weight (metric tons)	Value
Ferrosilicon:			
More than 55% silicon:			
Canada	8,420	5,050	$7,840,000
China	72	60	50,500
Colombia	27	20	37,400
Costa Rica	1	1	2,570
Hong Kong	5	3	3,930
Jamaica	3	2	3,650
Malaysia	22	16	31,200
Mexico	1,190	715	1,470,000
Netherlands	97	75	158,000
Total	9,830	5,940	9,590,000
Other ferrosilicon:			
Australia	10	5	12,800
Canada	2,680	1,340	2,700,000
Colombia	76	36	104,000
Costa Rica	9	5	11,600
Germany	41	18	41,400
Indonesia	2	1	3,050
Italy	33	17	53,300
Mexico	739	371	827,000
Philippines	2	1	9,090
Spain	20	10	22,500
Other	4	2	3,050
Total	3,610	1,800	3,780,000
Grand total ferrosilicon	13,400	7,740	13,400,000
Metal:			
More than 99.99% silicon:			
China	1,390	1,390	72,500,000
Finland	179	179	5,800,000
Germany	2,070	2,070	88,200,000
Italy	118	118	9,570,000
Japan	7,110	7,110	451,000,000
Korea, Republic of	907	907	57,800,000
Malaysia	73	73	12,500,000
Norway	1,790	1,790	66,600,000
Taiwan	407	407	20,700,000
United Kingdom	392	392	23,500,000
Other	376	376	22,200,000
Total	14,800	14,800 [2]	830,000,000
99.00%-99.99% silicon:			
Brazil	867	860	2,270,000
China	120	119	329,000
France	171	170	415,000
Germany	119	118	290,000
India	29	29	78,800
Japan	101	100	232,000
Mexico	30	29	49,800
Spain	32	32	79,300
Sweden	33	32	46,000
United Kingdom	147	145	207,000
Other	131	130	211,000
Total	1,780	1,770	4,210,000

See footnotes at end of table.

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TABLE 5—Continued

U.S. EXPORTS OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 2005[1]

Country	Gross weight (metric tons)	Contained weight (metric tons)	Value
Metal—Continued:			
Other silicon:			
Brazil	86	83	$113,000
Canada	3,080	2,990	3,180,000
China	1,060	1,030	1,450,000
Germany	180	174	240,000
Japan	418	406	1,270,000
Korea, Republic of	589	572	1,180,000
Mexico	309	301	903,000
Netherlands	334	321	2,770,000
Philippines	82	79	108,000
Russia	224	218	296,000
Other	407	395	1,150,000
Total	6,760	6,560	12,700,000
Grand total silicon metal	23,300	23,100	847,000,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Contained weight estimated using gross weight.

Source: U.S. Census Bureau.

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TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 2005[1]

Country	Gross weight (metric tons)	Contained weight (metric tons)	Value
Ferrosilicon:			
55%-80% silicon, more than 3% Ca:			
Argentina	131	91	$204,000
Belgium	3	2	9,840
China	38	17 [2]	53,000
France	414	252	641,000
Germany	10	5	13,300
United Kingdom	9	6	64,300
Total	606	373	985,000
55%-80% silicon, other:			
Brazil	1,600	1,200	1,380,000
Canada	11,900	8,990	10,800,000
China	108,000	81,700	69,500,000
France	3,870	2,630	7,130,000
Germany	441	345	2,190,000
Kazakhstan	103	15 [2]	69,400
Norway	20,000	15,000	19,200,000
Russia	40,900	30,500	27,300,000
Slovenia	274	191	406,000
Venezuela	47,400	35,900	36,300,000
Other	109	78	305,000
Total	235,000	177,000	175,000,000
Magnesium ferrosilicon:			
Argentina	3,450	1,560	3,540,000
Brazil	2,280	1,020	2,050,000
Canada	6,450	2,980	6,220,000
China	7,130	3,290	5,230,000
France	393	198	368,000
India	119	54	135,000
Japan	350	169	495,000
Netherlands	878	409	719,000
Norway	8,880	4,140	8,020,000
South Africa	76	35	85,500
Other	31	17	69,500
Total	30,000	13,900	26,900,000
Other ferrosilicon:			
Brazil	145	64	273,000
Canada	8,780	2,470	6,880,000
China	13,900	3,230	4,600,000
France	32	19	78,700
Germany	(3) [2]	30	6,990
India	251	149	271,000
Russia	1,520	697	656,000
Slovakia	3	1	5,690
Ukraine	22	11	18,300
United Kingdom	20	3	27,800
Total	24,700	6,670	12,800,000
Grand total ferrosilicon	290,000	197,000	215,000,000

See footnotes at end of table.

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TABLE 6—Continued
U.S. IMPORTS FOR CONSUMPTION OF FERROSILICON AND SILICON METAL, BY GRADE AND COUNTRY, IN 2005[1]

Country	Gross weight (metric tons)	Contained weight (metric tons)	Value
Metal:			
More than 99.99% silicon:			
China	27	27	$1,080,000
Denmark	3	3	1,210,000
Germany	849	849	65,600,000
Italy	322	322	13,000,000
Japan	538	538	40,300,000
Korea, Republic of	119	119	8,390,000
Philippines	179	179	253,000
Poland	10	10	29,900
Spain	6	6	52,200
Taiwan	5	5	479,000
Other	12	12	858,000
Total	2,070	2,070 [4]	131,000,000
99.00%-99.99% silicon:			
Australia	8,330	8,290	14,200,000
Brazil	51,500	51,200	71,500,000
Canada	16,800	16,700	27,100,000
France	1,560	1,550	2,140,000
India	114	113	167,000
Norway	7,010	5,760 [2]	15,500,000
Philippines	1,850	1,490 [2]	2,680,000
South Africa	34,800	34,500	52,300,000
Sweden	36	24 [2]	255,000
United Kingdom	189	83 [2]	763,000
Other	40	40	71,600
Total	122,000	120,000	187,000,000
Other silicon:			
Brazil	11,400	11,200	16,800,000
Canada	11,600	10,100	18,300,000
China	2,440	2,390	2,630,000
France	520	513	633,000
Germany	230	221	564,000
Norway	3,560	3,500	5,480,000
South Africa	230	224	274,000
Sweden	444	72	494,000
Ukraine	1,040	1,020	1,320,000
United Kingdom	342	329	553,000
Other	947	688	1,400,000
Total	32,800	30,300	48,500,000
Grand total silicon metal	157,000	152,000	366,000,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]All or part of these data have been referred to the U.S. Census Bureau for verification.
[3]Less than ½ unit.
[4]Contained weight estimated using gross weight.

Source: U.S. Census Bureau.

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SILVER

By William E. Brooks

Domestic survey data and tables were prepared by Mahbood Mahdavi and Wanda G. Wooten, statistical assistants, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

In 2005, the United States produced 1,230 metric tons (t) of silver, a decrease of 20 t compared with 2004 silver production of 1,250 t, and accounted for 6% of global mine production of 20,200 t. Approximately 99% of domestic silver was produced from base-metal ores at 15 mines and from precious-metal ores at 10 mines. Silver was produced in 11 States in 2005, and Alaska remained the country's leading silver producer followed by Nevada, known as the "Silver State," and Idaho, famous for the Coeur d'Alene District in the Silver Valley.

Silver prices averaged $7.34 per troy ounce in 2005, approximately 10% greater than the 2004 average of $6.69 per troy ounce. Since 2003, the spot silver price has more than doubled and reached a high of $9.17 in December 2005. On a global scale, traditional use categories for silver include its use in coins and medal fabrication; industrial applications, including electrical and electronics components; jewelry and silverware; and photography. The plan for holding physical silver in an exchange traded fund (ETF) may represent a new stock category for silver. Silver's well-known antibacterial properties indicate potential new applications, for example, in construction as a wood preservative and in cellular phone covers to reduce the spread of bacteria (Canadian Paediatric Society, 2002; Silver Institute, The, 2006§[1]). In 2005, the global use of silver continued to decline in jewelry, photography, and silverware. There was increased use of silver in coin and medal fabrication and for industrial applications, specifically electronics.

U.S. imports for consumption of refined silver in 2005 totaled approximately 3,880 t, 220 t less than in 2004 (table 1). Mexico (49%) was the leading source of imported refined silver into the United States, followed by Canada (31%) and Peru (15%). Canada (38%) was the leading destination for exported silver, followed by Switzerland (29%) and the United Kingdom (11%).

In 2005, silver was mined in approximately 60 countries, and Peru was the leading producer with 3,200 t, followed by Mexico (2,900 t) and China (2,500 t). World mine production increased in 2005 by 400 t, 2% more than the 2004 production. In most countries, silver production has remained relatively stable; however, silver production in Russia more than tripled during a 3-year period to 1,350 t in 2005 from 400 t in 2002. Production was mainly from the Dukat Mine in eastern Russia, which is the world's third largest silver deposit in terms of reserves and has been Russia's leading silver mine since 1980.

Legislation and Government Programs

The primary mission of the U.S. Mint is to produce an adequate volume of circulating coinage; in 2004 and 2005, circulating coin production was 13.2 billion and 15.3 billion coins per year, respectively (U.S. Mint, 2006§). The Mint's responsibilities also include custody and protection of the Nation's $100 billion in gold and silver assets; producing proof and uncirculated coins, commemorative coins, and medals; manufacturing and selling platinum, gold, and silver bullion coins; and receiving and processing mutilated coins. Its six facilities are in Denver, CO; Fort Knox, KY; Philadelphia, PA; San Francisco, CA; Washington, DC; and West Point, NY.

Production

In the United States, silver was produced as the principal mineral commodity from the Coeur Rochester Mine, an open pit operation in northwestern Nevada, and the world's eighth leading primary silver-producing mine (Silver Institute, The, 2006§). Silver was also produced as a byproduct from copper, copper-molybdenum, gold, and lead-zinc ores at other mines in the United States. Domestic mine production data were obtained from 25 mines in 10 States, most of which responded to requests from the U.S. Geological Survey (USGS) for data, representing about 99% of U.S. production. Domestic mine production of silver, which totaled 1,230 t in 2005, was only slightly less than the 2004 mine production of 1,250 t.

The minor decline in overall domestic silver mine production was principally owing to reduced access to areas of the Galena Mine in Shoshone County, ID, that were being redeveloped and suspension of open pit mining at the Montana Tunnels Mine in Jefferson County, MT, in October. At the Bingham Canyon Mine in Utah, production increased owing to higher mill throughput and a rise in average silver grade (Silver Institute, The, 2006, p. 23). At the Red Dog Mine in Alaska, Teck Cominco Limited (Vancouver, British Columbia, Canada) received byproduct silver revenues for 61,300 kilograms (kg) (reported as 1,970,000 troy ounces) of silver in 2005 (Teck Cominco Limited, 2006§). At the Montana Tunnels Mine, reserves averaged 6.6 grams per metric ton (g/t) (reported as 0.212 troy ounces per metric ton) silver and 0.5 g/t (reported as 0.016 troy ounces per metric ton) gold (Apollo Gold Corp., 2006, p. 10). For 2005, Hecla Mining Company (Coeur d'Alene, ID) reported producing about 200,000 kg of silver at an average cost of $2.96 per ounce. Hecla reported producing approximately 75,000 kg of silver from the Lucky Friday Mine in Idaho and approximately 90,000 kg of silver from its share of the Greens Creek Unit in Alaska (Hecla Mining Company, 2006§).

As of December 31, 2005, Revett Minerals Inc. (Spokane Valley, WA) reported that proven and probable ore reserves at the Troy Mine increased to about 10.9 million metric tons (Mt) of ore from 7.9 Mt as of December 31, 2004. This represents an increase in the operating life of the Troy Mine of approximately 1.4 years (Revett Minerals Inc., 2006§).

[1]References that include a section mark (§) are found in the Internet References Cited section.

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Consumption

Silver, along with copper and gold, were the metals used by ancient man for artisanal jewelry and tools. Occurrences of silver are widespread and argentiferous galena, one of silver's chief ore minerals, is relatively easy to smelt. Silver is malleable, reflective, and it has the highest electrical and thermal conductivity of all the metals. It remains one of the least expensive of the precious metals. Its physical properties and intrinsic value result in silver's wide use for coins and medal fabrication, industrial applications including electrical and electronics components, jewelry and silverware, and, photography (Etris, 1997, p. 163; Silver Institute, The, 2006, p. 10). World consumption of silver was 28,500,000 kg in 2005, up from 27,400,000 kg in 2004. Domestic consumption of silver was approximately 5,900,000 kg in 2005, up from 5,625,000 kg in 2004 (Silver Institute, The, 2006, p. 46).

Coins and Medal Fabrication.—Approximately 518,750 kg of silver was used for coins and medals in the United States in 2005, a 7% increase from the 484,000 kg used in 2004 (Silver Institute, The, 2006, p. 69). Historically, silver was more widely used than gold for coins but has been phased out of use in most circulating coins. Currently, its most significant use in this application is in medals and commemorative pieces. The Northwest Territorial Mint, Auburn, WA, produces silver, gold, platinum, and palladium commemorative and specialty coins for retirements, special events, and investments. They have a contract with Pan American Silver Corporation (Vancouver, British Columbia, Canada) and use approximately 94,000 kilograms per year of silver and look to increase that amount to about 156,000 kg in the coming years (R. B. Hansen, President, Northwest Territorial Mint, oral commun., September 22, 2006).

Industrial Applications.—Approximately 3,125,000 kg of silver was used in the United States in 2005 for industrial applications, a 6% increase from the 2,937,000 kg used in 2004 (Silver Institute, The, 2006, p. 50). Silver is used in many applications such as conductors, contacts, fuses, timers, and switches because it is an excellent electrical and thermal conductor. It is also used in conductive adhesives; in the preparation of thick-film, silver-palladium pastes for use as silkscreen circuit paths in multilayer ceramic capacitors; in the manufacture of membrane switches; in flat-screen televisions using plasma display panels; in silver-backed solar mirrors; as a silver film in electrically heated automobile windows; in smart cards; and in solar cells. A small amount of silver is used as a miniature antenna in Radio Frequency Identification Devices (RFID) that are used in passports, on packages, and to keep track of inventory shipments (Free Market News Network, 2005a§). Silver is an important component in dental amalgam and other dental applications. It is also used in the bearings in jet engines and in silver oxide batteries for cameras and watches.

Jewelry and Silverware.—The U.S. demand for silver in 2005 in this market sector was 491,000 kg, somewhat higher than the 481,000 kg used for fabrication in 2004 (Silver Institute, The, 2006, p. 62). World consumption for silver in jewelry and silverware increased by about 1% to 7,800,000 kg in 2005 from 7,750,000 kg in 2004. A tarnish-resistant sterling silver alloy containing germanium has been developed. Any tarnish that does develop can be removed with a damp sponge, thereby eliminating the need for harsh chemicals (Silver Institute, The, 2005§).

Photography.—In the United States, silver use in photography declined from its maximum of 2,312,000 kg in 1999 to 1,750,000 kg in 2005, which was an increase of only about 2% above the 1,719,000 kg used in 2004 (Silver Institute, The, 2006, p. 58). Digital photography and electronic imaging continued to replace silver-halide use in photography, and Eastman Kodak Company announced that it would miss earnings targets in 2005 (CRU Monitor, 2005§). In the period 1999-2005, worldwide use of silver in photography continued an overall decline from a maximum of 7,125,000 kg in 1999 to 5,156,000 kg in 2005. Worldwide silver use in 2005 was approximately 10% lower than the 5,656,000 kg used in 2004. Photographic use categories included commercial photography, dental and industrial x rays, graphic arts, and medical x rays. The overall decline in the use of silver for photographic uses began in 2000 mainly because of competition from digital camera technology and the resulting decline in the production of color film.

Other.—In 2005, silver was used for batteries, bearings, brazing and soldering, catalysts, medical applications, mirrors, solar energy, and water purification (Silver Institute, The, 2006§). Its antibacterial and biocidal qualities, which have been known since antiquity, indicate applications in bandages, burn and wound care, cellular phone covers, classroom paper products, clothing to eliminate odor, contraceptives, surface disinfectants, surgical bone cements, and as a wood-preservative because it inhibits mold and mildew growth. Ionic or "colloidal" silver is recognized for its broad spectrum of antimicrobial properties and has been applied to catheters, intravenous needles, and other medical devices (Slaven, 2005, p. 2). Dental amalgam, though in declining use because of its mercury content, may contain 34% to 38% silver (Lawrence, 1995).

Prices

In 2005, the average price of silver was $7.34 per troy ounce, which was 10% above the 2004 average price of $6.69 per ounce. The last time that the average price of silver was above $6.00 per ounce was in 1987 and 1988, when the average prices were $6.99 per ounce and $6.53 per ounce, respectively. Prices for copper, gold, and silver all rose significantly during 2005 as part of a boom in commodity investment as consumption increased at a faster rate than production (Silver Institute, The, 2006, p. 14).

Gold Exchange Traded Funds (ETF) have been available since 2003 and passage of a similarly modeled silver ETF was proposed in 2005. The proposed silver ETF was expected to increase liquidity, attract new investors, and provide advantages to investors because of the inherent difficulties of investor purchasing and storing physical silver (Free Market News Network, 2005b§).

Trade

The United States imported 3,880 t of refined silver and exported 166 t of refined silver in 2005 (table 1). The United

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States exported approximately 300 t of bullion, dore, and ores and concentrates in 2005. Principal destinations for bullion were Canada (116 t), Australia (17 t), and Uruguay (17 t). Principal destinations for dore were Switzerland (88 t) and the United Kingdom (34 t).

World Review

World mine production increased to 20,200 t in 2005, a 2% increase from 19,800 t produced in 2004 (table 8). Silver production increased in the world's leading silver producing country, Peru (4%), and also in Mexico (12%) and Russia (6%). Production increased at the Dukat Mine in Russia because of expanded capacity (Silver Institute, The, 2006, p. 20). In 2005, above ground stocks of silver rose approximately 10%, to 6,931 t from 6,290 t in 2004 (Silver Institute, The, 2006, p. 30).

China.—In September 2005, The Silver Institute released a report prepared by GFMS Ltd. entitled "A Review of the Chinese Silver Market." In April, Silvercorp Metals, Inc. announced silver resources of 1,340,000 kg of silver at its Ying silver project in Henan (Silvercorp Metals, Inc., 2005§). However, most of China's silver comes from a considerable number of small mines rather than large mines. China is an importer and exporter of silver bullion, and its scrap supply comes mainly from photographic and electronic uses (GFMS Ltd., 2005§). China produced an estimated 2,500 t of silver in 2005, which was only slightly more than 2004 production of 2,450 t (table 8). The global commodities boom has encouraged nearly 60 mining companies to explore for gold in China (Antaike Precious and Minor Metals Monthly, 2005). This may ultimately result in increased byproduct silver production as new gold mines are opened.

Mexico.—In 2005, Mexico was the second leading producer of silver. Industrias Peñoles S.A. de C.V. produced 1,469,000 kg (47 million troy ounces) in 2005, a 7% increase compared with the 2004 production of 1,375,000 kg (44 million troy ounces) (Silver Institute, The, 2006, p. 20).

Peru.—Peru was the leading silver producer in 2005. Five mines in Peru are among the world's top 15 silver-producing mines. One of these, the Morococha Mine, produced approximately 84,000 kg (reported as 2.7 million troy ounces) of silver in 2005 (Pan American Silver Corporation, 2005). The overall increase in production for these five Peruvian mines, which comprised 27% of total silver production in Peru, was approximately 5%, to 858,000 kg (27.6 million troy ounces) in 2005 from 818,000 kg (26.3 million troy ounces) in 2004 (Silver Institute, The, 2006, p. 87). Silver jewelry and other goods are sold widely in the artisanal markets in Lima and in Huancayo, which is the center of small-scale artisanal silver production.

Current Research and Technology

The recent introduction of televisions with plasma display panels has boosted the demand for silver as larger sizes may contain up to a troy ounce of silver. Sales for the televisions are expected to increase to about 10 million units by 2008 (Silver Institute, The, 2006, p. 57). Bandages with trace amounts of silver (0.003%) have been approved by the U.S. Food and Drug Administration. Lab testing of these antibacterial bandages reduced the growth of S. aureus, E. coli, E. hirae, and P. aeruginosa for 24 hours (Walgreen Co., 2005§; Wolf, 2005§).

Silver-base disinfectants have been introduced as a low cost, environmentally sensitive option for use in care centers, food processing facilities, and sports facilities. Silver is used in new contraceptives to kill disease pathogens such as Candida and coliform bacillus, and may prevent sexually transmitted diseases (Smith, 2005§).

Photographic waste from medical, dental, and consumer photo processing can generate approximately 100 million gallons per year of wastewater. This wastewater, which contains approximately 20 million troy ounces of silver worth $220 million, can be treated to recover and recycle silver and produce fertilizers (John Whitney, President, Itronics, Inc., oral commun., September 22, 2006).

Outlook

In 2005, reported world silver consumption was 28,364 t, or 4% higher than the 27,313 t used in 2004 (Silver Institute, The, 2006, p. 71). Except in the United States, silver use in photography continued to fall, mainly because of a reduction in the output of color film as digital photography continued to erode the use of silver in the photographic market. The decline in traditional cameras and silver use is indicated by the installation of new digital camera systems in hospitals in Alberta, Canada (Eastman Kodak Company, 2005§). Canon, Konica, and Nikon have announced plans to leave the film-camera business (Musgrove, 2006; Noguchi, 2006). Silver use in photography is expected to level off as silver continues to be used in making high-quality prints from digital sources.

The effect of the proposed silver ETF, though similar in structure to the gold ETF, may prove to be important as silver is diverted from traditional uses for repository in the ETF. This will attract new investors and silver prices may continue to rise. Batteries and fuel cells that use metals, specifically silver, are expected to increase by 6% per year through 2007. Alkaline-base fuel cells are of interest because they have cost and technical advantages that include the ability to use nonplatinum, and therefore, less expensive, catalysts such as gold or silver (Freedonia Group, The, 2005§). Silver's uses in construction, electronics, medicine, superconductivity, water purification, wood preservatives, wound care, and many others will continue to increase.

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TABLE 1
SALIENT SILVER STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Mine production:						
Quantity	metric tons	1,740	1,350	1,240	1,250	1,230
Value	thousands	$245,000	$201,000	$196,000	$268,000	$289,000
Refinery production:						
Domestic and foreign ores and concentrates	metric tons	2,640	2,580	2,580	1,140	2,530
Scrap (old and new)	do.	1,060	1,030	1,010	1,920	981
Exports, refined	do.	783	680	181	422	166
Imports for consumption, refined	do.	3,340	4,300	4,510	4,100	3,880
Stocks, December 31:						
Industry	metric tons	360	280	93	131	86
Futures exchanges	do.	3,250	3,290	3,430	3,580	3,380
U.S. Department of the Treasury	do.	220	220	220	220	NA
National Defense Stockpile	do.	21	--	--	--	NA
Price, average[2]	dollars per troy ounce	$4.39	$4.62	$4.91	$6.69	$7.34
Employment, mine and mill workers[3]		1,100	1,100	1,200	NA	NA
World, mine production	metric tons	18,700 r	18,800 r	18,800 r	19,800 r	20,200 e

eEstimated. rRevised. NA Not available. -- Zero.

[1]Data are rounded to no more than three significant digits, except prices.

[2]Price data are the annual Handy & Harman quotations published in Platts Metals Week.

[3]Employment data are from the Mine Safety and Health Administration.

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TABLE 2

MINE PRODUCTION OF SILVER IN THE UNITED STATES, BY STATE[1]

(Kilograms)

State	2003	2004	2005
California	958	801	W
Nevada	322,000	302,000	276,000
Other[2]	916,000	943,000	949,000
Total	1,240,000	1,250,000	1,230,000

W Withheld to avoid disclosing company proprietary data; included with "Other."

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes Alaska, Arizona, California, Colorado, Idaho, Missouri, Montana, New Mexico South Dakota, and Utah.

TABLE 3

LEADING SILVER-PRODUCING MINES IN THE UNITED STATES IN 2005, IN ORDER OF OUTPUT[1]

Rank	Mine	County and State	Operator	Source of silver
1	Greens Creek	Juneau, AK	Kennecott Greens Creek Mining Co.	Zinc ore.
2	Red Dog	Northwest Arctic, AK	Teck Cominco Alaska Inc.	Lead-zinc ore.
3	Coeur Rochester	Pershing, NV	Coeur d'Alene Mines Corp.	Silver ore.
4	Bingham Canyon	Salt Lake, UT	Kennecott Utah Copper Corp.	Copper-molybdenum ore.
5	Lucky Friday	Shoshone, ID	Hecla Mining Company	Silver ore.
6	Midas	Elko, NV	Newmont Mining Corporation	Gold ore.
7	Galena	Shoshone, ID	Silver Valley Resources Corp.	Silver ore.
8	Round Mountain	Nye, NV	Kinross Gold Corporation	Gold ore.
9	Brushy Creek	Reynolds, MO	Doe Run Resources Corp.	Lead ore.
10	Bagdad	Yavapai, AZ	Phelps Dodge Corp.	Copper-molybdenum ore.
11	Montana Tunnels	Jefferson, MT	Apollo Gold Corp.	Gold ore.
12	Continental Pit	Silver Bow, MT	Montana Resources	Copper-molybdenum ore.
13	Fletcher	Reynolds, MO	Doe Run Resources Corp.	Lead ore.
14	Eastern Nevada Operations	Elko, Eureka, NV	Newmont Mining Corporation	Gold ore.
15	Buick	Iron, MO	Doe Run Resources Corp.	Lead ore.
16	Mission Complex	Pima, AZ	ASARCO Incorporated	Copper ore.
17	Denton-Rawhide	Mineral, NV	Kennecott Minerals Company	Gold ore.
18	Chino	Grant, NM	Phelps Dodge Corp.	Copper-molybdenum ore.
19	Viburnum (#28 and #35)	Iron, MO	Doe Run Resources Corp.	Lead ore.
20	Sweetwater	Reynolds, MO	do.	Do.
21	Meikle	Elko, NV	Barrick Gold Corporation	Gold ore.
22	Ray	Pinal, AZ	ASARCO Incorporated	Copper ore.
23	Betze-Post	Eureka, NV	Barrick Gold Corporation	Gold ore.
24	Cresson	Teller, CO	Cripple Creek & Victor Gold Mining Co.	Do.
25	Kettle River	Ferry, WA	Kinross Gold Corporation	Do.

[1]The mines on this list accounted for 99% of U.S. mine production in 2005.

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TABLE 4
U.S. EXPORTS OF SILVER, BY COUNTRY[1]

Year and country	Silver ores and concentrates		Bullion		Dore		Total	
	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)
2004	1,560	$306	302,000	$64,500	79,800	$18,800	384,000	$83,600
2005:								
Armenia	369	75	--	--	30	7	399	82
Australia	--	--	17,100	4,230	--	--	17,100	4,230
Brazil	2,030	491	--	--	--	--	2,030	491
Canada	--	--	116,000	34,200	93	28	116,000	34,200
China	--	--	32	8	--	--	32	8
Denmark	--	--	275	50			275	50
Finland	17	3	553	128	2,340	344	2,910	475
Germany	--	--	782	140	--	--	782	140
Guatemala	--	--	316	81			316	81
Hong Kong	--	--	98	18	--	--	98	18
Ireland	212	42	29	4	--	--	241	46
Italy	17	3	--	--	--	--	17	3
Japan	17	3	--	--	--	--	17	3
Korea, Republic of	545	108	--	--	--	--	545	108
Mauritius	6	4	--	--	--	--	6	4
Mexico	--	--	2,960	563	46	10	3,000	573
Morocco	--	--	38	13	--	--	38	13
Netherlands	--	--	9,550	2,030	--	--	9,550	2,030
Norway	--	--	--	--	3,910	971	3,910	971
Russia	48	6	--	--	--	--	48	6
Singapore	--	--	--	--	2,960	618	2,960	618
Spain	7	4	--	--	106	25	113	29
Switzerland	--	--	--	--	88,000	21,400	88,000	21,400
Taiwan	83	15	--	--	--	--	83	15
Thailand	21	9	--	--	--	--	21	9
Trinidad and Tobago	163	43	--	--	--	--	163	43
United Kingdom	146	29	996	236	34,400	11,600	35,600	11,800
Uruguay	--	--	17,500	4,210	--	--	17,500	4,210
Total	3,680	834	166,000	45,900	132,000	35,000	302,000	81,700

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 5
U.S. EXPORTS OF SILVER, BY COUNTRY[1]

Year and country	Other unwrought silver		Metal powder		Silver nitrate		Semimanufactured forms[2]		Waste and scrap	
	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
2004	39,600	$8,690	708,000	$122,000	61,500	$5,720	269,000	$48,300	2,240,000	$424,000
2005:										
Aruba	109	24	--	--	--	--	--	--	--	--
Australia	--	--	--	--	342	24	422	83	--	--
Bahamas, The	247	54	--	--	--	--	--	--	--	--
Belgium	40	11	2,350	423	110	3	2,680	474	170,000	34,400
Bermuda	156	34	--	--	--	--	--	--	--	--
Brazil	17	4	--	--	733	82	2,190	372	145	50
Canada	12,500	3,350	21,000	3,590	35,000	1,690	134,000	23,300	774,000	119,000
Cayman Islands	111	41	--	--	--	--	--	--	--	--
China	175	39	6,330	1,080	8,540	1,300	1,890	354	611,000	74,900
Colombia	--	--	41	7	--	--	97	16	693	226
Czech Republic	--	--	120	20	--	--	--	--	102	22
Denmark	35	8	16	3	--	--	140	24	--	--
Dominican Republic	1,560	352	--	--	--	--	1,190	203	--	--
Egypt	--	--	--	--	--	--	103	17	--	--
Finland	--	--	309	52	--	--	16	3	--	--
France	85	18	26,300	4,480	--	--	7,940	1,430	--	--
Germany	150	38	89,600	15,200	53	23	7,280	1,260	398,000	115,000
Hong Kong	266	57	28,700	4,890	--	--	13,500	2,290	33,200	4,750
India	122	27	--	--	--	--	577	99	443	61
Ireland	--	--	142	24	--	--	--	--	--	--
Israel	--	--	--	--	151	28	1,210	216	754	153
Italy	239	58	321	59	--	--	2,160	382	529,000	118,000
Jamaica	481	120	--	--	--	--	--	--	--	--
Japan	796	257	205,000	35,200	--	--	2,890	499	15,900	37,200
Jordan	200	53	--	--	--	--	--	--	--	--
Kenya	--	--	--	--	--	--	276	47	--	--
Korea, Republic of	570	109	232,000	40,100	265	24	358	65	33,400	4,510
Kuwait	--	--	--	--	120	6	--	--	--	--
Lithuania	--	--	--	--	--	--	316	54	--	--
Lebanon	--	--	144	26	--	--	--	--	--	--
Malaysia	--	--	--	--	--	--	--	--	6,520	852
Mauritius	--	--	--	--	--	--	1,710	298	--	--
Mexico	501	110	11,500	1,970	5,020	454	48,200	8,890	73	21
Netherlands	--	--	2,690	473	447	13	8,300	1,430	37	8
Netherlands Antilles	678	158	--	--	--	--	245	42	1	3
New Zealand	--	--	156	28	107	6	--	--	--	--
Nigeria	--	--	--	--	127	5	--	--	--	--

See footnotes at end of table.

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TABLE 5—Continued
U.S. EXPORTS OF SILVER, BY COUNTRY[1]

Year and country	Other unwrought silver		Metal powder		Silver nitrate		Semimanufactured forms[2]		Waste and scrap	
	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
2005—Continued:										
Philippines	1	3	--	--	211	16	991	169	188	66
Portugal	--	--	--	--	195	$12	--	--	--	--
Saudi Arabia	--	--	--	--	--	--	--	--	175,000	$34,700
Singapore	--	--	16,500	$2,830	--	--	4,620	$808	168	22
Slovenia	--	--	--	--	--	--	--	--	477	62
South Africa	--	--	26	5	27	4	--	--	3,410	539
Spain	--	--	--	--	--	--	23,300	3,970	1,190	154
Sri Lanka	--	--	--	--	115	17	--	--	--	--
Sweden	--	--	12,600	2,140	93	6	--	--	55,100	11,800
Switzerland	13	$3	419	76	--	--	1,210	223	705	5,900
Taiwan	133	30	79,900	13,600	--	--	6,880	1,230	39,500	3,560
Thailand	87	26	151	26	--	--	21,900	4,220	3,740	659
Trinidad and Tobago	--	--	--	--	2	3	164	40	--	--
United Arab Emirates	--	--	--	--	124	24	46	8	1	7
United Kingdom	444	113	72,000	12,400	4,840	448	10,200	1,790	24,700	8,900
Vietnam	411	79	--	--	--	--	--	--	1,050	168
Other	407	106	80	14	--	--	722	132	93	98
Total	20,500	5,280	808,000	139,000	56,600	4,190	308,000	54,400	2,880,000	576,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Containing 99.5% or more by weight of silver.

Source: U.S. Census Bureau.

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TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF SILVER, BY COUNTRY[1]

Year and country	Silver ores and concentrates		Ash and residues		Bullion		Dore		Total	
	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)	Silver content (kilograms)	Value (thousands)
2004	2,220	$1,410	6,710	$1,530	3,410,000	$728,000	346,000	$117,000	3,760,000	$848,000
2005:										
Australia	--	--	--	--	25,400	4,680	--	--	25,400	4,680
Belgium	--	--	--	--	118	29	--	--	118	29
Canada	433	318	--	--	1,290,000	300,000	3,960	713	1,290,000	301,000
Chile	--	--	--	--	41,000	9,810	37,200	8,690	78,200	18,500
Colombia	--	--	--	--	403	97	2,090	536	2,500	633
France	--	--	--	--	1,600	348	--	--	1,600	348
Germany	--	--	--	--	20,300	4,590	--	--	20,300	4,590
Honduras	--	--	--	--	--	--	706	169	706	169
Mexico	--	--	--	--	1,910,000	447,000	138,000	47,700	2,050,000	494,000
Panama	--	--	--	--	167	61	41	8	208	69
Peru	--	--	--	--	514,000	119,000	118,000	31,600	632,000	151,000
Philippines	--	--	--	--	649	104	--	--	649	104
Poland	--	--	--	--	40,000	9,180	--	--	40,000	9,180
Spain	--	--	--	--	--	--	286	54	286	54
Taiwan	--	--	2,630	769	--	--	--	--	2,630	769
United Kingdom	--	--	--	--	34,700	7,210	--	--	34,700	7,210
Total	433	318	2,630	769	3,880,000	902,000	300,000	89,500	4,180,000	993,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 7

U.S. IMPORTS FOR CONSUMPTION OF SILVER, BY COUNTRY[1]

Year and country	Other unwrought silver		Metal powder		Silver nitrate		Semimanufactured forms[2]		Waste and scrap	
	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
2004	342,000	$69,600	27,400	$6,920	289	$66	52,300	$11,900	2,020,000	$160,000
2005:										
Australia	--	--	43	7	--	--	1,470	156	117	705
Brazil	--	--	--	--	--	--	16,500	4,230	41,600	1,620
Canada	67,300	15,900	2,070	293	--	--	1,630	269	164,000	26,200
China	--	--	163	16	--	--	294	57	49,000	1,930
Colombia	--	--	--	--	--	--	--	--	24,500	653
Costa Rica	--	--	--	--	--	--	--	--	139,000	8,810
Dominican Republic	--	--	--	--	--	--	--	--	2,740	4,750
Finland	--	--	--	--	--	--	--	--	18,600	60
France	--	--	1,090	319	--	--	5,320	1,160	1,480,000	6,130
Germany	228	51	2,550	615	--	--	1,760	499	4,140	8,860
Guatemala	--	--	--	--	--	--	--	--	333	2,410
Honduras	--	--	--	--	--	--	--	--	44	470
Hong Kong	--	--	--	--	--	--	--	--	775	106
India	1,210	286	--	--	33	4	91	28	28,800	174
Indonesia	--	--	--	--	--	--	--	--	11,300	1,000
Ireland	--	--	--	--	--	--	--	--	15,200	685
Israel	--	--	--	--	--	--	--	--	29,200	119
Italy	135	65	--	--	--	--	--	--	51,800	14,000
Jamaica	--	--	--	--	--	--	--	--	3,630	24
Japan	707	248	20,900	5,220	--	--	--	--	10,900	2,030
Jordan	25	5	--	--	--	--	--	--	900	128
Korea, Republic of	--	--	--	--	--	--	831	105	9,560	792
Malaysia	--	--	450	78	--	--	--	--	66,500	1,230
Mexico	286,000	63,700	--	--	--	--	2,690	642	1,370,000	33,800
Netherlands	1,080	109	454	94	--	--	--	--	10	3
Panama	--	--	--	--	--	--	--	--	106	721
Peru	--	--	--	--	--	--	149,000	32,500	3	50
Philippines	63	37	66	11	--	--	--	--	391	321
Singapore	--	--	(3)	6	--	--	--	--	64	935
South Africa	--	--	--	--	--	--	--	--	20,100	203
Spain	--	--	--	--	--	--	278	72	--	--
Switzerland	56	13	301	83	--	--	150	39	--	--
Taiwan	--	--	13	2	84	13	--	--	31,600	2,530
Turkey	56	10	--	--	--	--	--	--	544	8
United Arab Emirates	--	--	--	--	--	--	--	--	5,500	220

See footnotes at end of table.

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TABLE 7—Continued

U.S. IMPORTS FOR CONSUMPTION OF SILVER, BY COUNTRY[1]

Year and country	Other unwrought silver		Metal powder		Silver nitrate		Semimanufactured forms[2]		Waste and scrap	
	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)
2005—Continued:										
United Kingdom	1	$5	1,180	$243	552	$101	17	$31	593,000	$15,500
Venezuela	--	--	--	--	--	--	--	--	110	555
Other	75	21	--	--	--	--	--	--	376	1,410
Total	357,000	80,400	28,400	6,840	201	30	180,000	39,900	3,640,000	126,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Containing 99.5% or more by weight of silver.

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TABLE 8
SILVER: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005[e]
Algeria[e]	2 [3]	1	1	(4) [r]	1
Argentina	153	126	134	172	175
Armenia	NA	6	4	4 [e]	4
Australia	1,970 [r]	2,077	1,868 [r]	2,183 [r]	2,047 [3]
Bolivia	411	450 [r]	465 [r]	407 [r]	419 [3]
Brazil[5]	46 [r]	33	31	35 [r]	36 [p]
Bulgaria[e]	57	60	50	50	50
Burma	2	1 [r]	1 [r]	1 [r]	1
Canada	1,320	1,408	1,310	1,337 [r]	1,122 [3]
Chile	1,349	1,210	1,313	1,360	1,400 [3]
China[e]	1,910	2,200	2,400	2,450	2,500
Colombia	7	7	10	9 [r]	7 [3]
Congo (Kinshasa)	--	2	36	33	54 [3]
Costa Rica[e]	(4)	(4)	(4)	(4)	(4)
Ecuador[e]	2	(4)	(4)	(4) [r, 3]	(4) [3]
Ethiopia	4	1	1	1 [r]	1
Finland	24	29	31 [r]	37 [r]	49 [3]
France[e]	1	1	1	1	(5)
Ghana	2	2	3 [r]	3 [r]	3
Greece	62	75	79	79	79
Honduras	47	53	48	48 [e]	48
India	50	52	51	15 [r]	32 [3]
Indonesia	270	294	285	263	280
Iran[e]	22	23	23	25 [r]	25
Ireland	19	5 [e]	9 [r]	7 [r]	6
Italy[r, 6]	4 [3]	4	4	3	3
Jamaica	(4)	(4) [e]	(4)	(4) [e]	--
Japan	80	81	79	79	54 [3]
Kazakhstan	982	893	827	733	832
Korea, North[e]	20	20	20	20	20
Korea, Republic of	1	7	12	5	4 [3]
Macedonia[e]	15	12	10	10	10
Malaysia	(4)	--	--	-- [r]	--
Mali[e]	-- [r]	-- [r]	-- [r]	-- [r]	--
Mexico	2,760	2,747	2,569	2,569 [r]	2,894 [3]
Mongolia[e]	27	27	27	28	28
Morocco	281	277	201	196 [r]	196
Namibia	20	44	45 [e]	27 [r]	20
New Zealand[e]	23	29 [r]	30 [r]	30 [r]	30
Nicaragua	3	2	2	2 [e]	2
Oman	3	4	-- [e]	-- [e]	--
Papua New Guinea[e]	76 [r]	64 [r]	62 [r]	38 [r]	63
Peru	2,571	2,870	2,921	3,060 [r]	3,193 [3]
Philippines[e]	31 [r]	9	10 [r]	9 [r]	2 [3]
Poland	1,194	1,229	1,237	1,344 [r]	1,300
Portugal	23 [e]	20	21	25 [r]	24
Romania[e]	18	15	18	20	20
Russia[e]	380	400	700	1,277 [3]	1,350 [3]
Saudi Arabia[e]	15 [3]	14	13	6	6
Serbia and Montenegro	6	7	10 [r]	10 [r]	10
South Africa	110	113	80	72 [r]	89
Spain	60 [e]	3	2	2 [e]	7
Sudan	2	3	3	3 [r, e]	3

See footnotes at end of table.

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TABLE 8—Continued
SILVER: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005[e]
Sweden	306	294 [r]	307	293	267 [3]
Tajikistan	5	5	5	5 [e]	5
Tanzania	7	8	8	13 [r]	13
Tunisia[e]	4 [3]	3	3	2	4
Turkey[e]	118	79 [r]	95 [r]	73 [r]	80
United States	1,740	1,350	1,240	1,250	1,230 [3]
Uzbekistan[e]	80	80	80	80	83
Zimbabwe	3	2 [r]	1 [r]	3 [r]	3 [3]
Total	18,700 [r]	18,800 [r]	18,800 [r]	19,800 [r]	20,200

[e]Estimated. [r]Revised. NA Not available. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Recoverable content of ores and concentrates produced unless otherwise specified. Table includes data available through August 13, 2006.

[3]Reported figure.

[4]Less than ½ unit.

[4]Includes the following quantities, in kilograms, identified as secondary silver: 2002-05—50,000.

[6]Includes production from imported ores.

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Slag—Iron and Steel

By Hendrik G. van Oss

In 2005, sales of iron and steel slags in the United States totaled about 21.6 million metric tons (Mt), an increase of almost 2% from sales in 2004; the overall value of sales in 2005 was about $372 million, up by about 13% (table 1). Ferrous slags are formed through the addition of slagging agents (chiefly limestone or dolomite) and/or fluxing materials to blast furnaces and steel furnaces to strip the impurities from iron ore, steel scrap, and other iron or steel feeds. The slag forms as a silicate melt that floats on top of the molten crude iron or steel and is tapped from the furnace separately from the liquid metal. After cooling to solid form, the slag is processed and may then be sold.

Most slags have very low unit values compared to iron and steel products. For this reason, iron and steel companies consider slag to be a nuisance and thus generally contract with outside slag-processing companies to remove it; commonly, the slag-processing company is also responsible for cooling the slag. Although the financial arrangements vary, typically the processing company receives the slag for free, crushes it to various marketable sizes, uses screens and magnetic separators to recover entrained metal from the slag (this metal to be returned to the furnace for a low charge), sells the slag on the open market, and pays a small percentage of the net slag sales revenues or profits to the iron or steel company. Also, slag may be returned to the furnaces for use as flux and as a supplemental source of iron; this return of slag is typically not reported as a sale.

A list of slag processors, processing sites, and the iron and steel companies serviced is provided in table 4. Apparent duplication at some sites is because certain processing contracts may have been transferred to other companies during the year, and integrated iron and steel plants may have contracts with different processing companies for different slag types produced at the plant. In some cases, the slag is cooled by one processing company or at one site and then is further processed and sold by another company or at another site.

Legislation and Government Programs

Demand for slag in the construction sector is influenced by Federal and State programs that affect construction spending levels. The main Federal funding program in recent years relating to construction has been the Transportation Equity Act for the 21st Century (TEA–21) and temporary funding continuations following its formal expiration in September 2003. Negotiations to reauthorize TEA–21 culminated with the August 10, 2005, signing into law of its replacement, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA–LU). This Act authorized Federal funding of surface transportation projects for the period 2005–09 at a total guaranteed minimum funding level of $244.1 billion for the period. In federally funded and other construction projects, slags are promoted as "sustainable" construction materials, mainly on the basis that slags substitute directly or indirectly for virgin raw materials (for example, natural stone aggregates in various applications, and natural raw materials for cement manufacture) or, in the specific case of ground granulated blast furnace slag (GGBFS), can partially substitute for portland cement in concrete.

Production

Data are generally unavailable from plants on the actual output of iron and steel slags for an extended series of production cycles (heats). This generally is because not all of the slag is tapped during a heat, and the amount of slag tapped is not routinely measured. Accordingly, there are no data on U.S. production of ferrous slags and few, if any, data on foreign production, although both can be estimated based on typical slag to metal production ratios, which in turn are related to the chemistry of the ferrous feeds to the furnaces. For typical iron ore grades (60% to 66% iron), a blast furnace will normally produce about 0.25 to 0.30 metric tons (t) of slag per ton of crude iron. For ore grades lower than average, the slag output will be higher—sometimes as much as 1.0 to 1.2 t of slag per ton of crude iron. Steel furnaces typically produce about 0.2 t of slag per ton of crude steel, but up to 50% of this slag is entrained metal, most of which is generally recovered during slag processing and returned to the furnace. The amount of marketable slag remaining after entrained steel removal is thus usually equivalent to about 10% to 15% of the crude steel output. Using these ratios and data for U.S. and world iron and steel production from the American Iron and Steel Institute (2005, p. 121-126), it was estimated that U.S. blast furnace slag production in 2005 was in the range of about 9 to 11 Mt, and world output was in the range of 196 to 237 Mt. Likewise, U.S. output of steel slag (after metal removal) in 2005 was estimated to be 10 to 14 Mt, and world output, 113 to 170 Mt.

Blast furnace slags, as sold, are of three main types—air-cooled, granulated, and pelletized (or expanded). Air-cooled blast furnace slag is formed by allowing the molten slag to cool relatively slowly under ambient conditions; final cooling can be accelerated with a water spray. The cooled material is hard and dense, although it can have a vesicular texture with closed pores. After crushing and screening, air-cooled slag is used mainly as an aggregate for various purposes (table 3). Granulated blast furnace slag is formed by quenching molten slag in water to form sand-sized particles of glass. The disordered structure of this glass gives the material moderate hydraulic cementitious properties when very finely ground. However, if this GGBFS can access free lime during hydration, the GGBFS develops strong hydraulic cementitious properties and is valued as a partial substitute for portland cement. Pelletized or expanded slag is cooled through a water jet, which leads to rapid steam generation and the development of innumerable vesicles within the slag. The vesicular texture reduces the overall density of

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the slag and allows for good mechanical binding with hydraulic cement paste. Blast furnace slag (generally air-cooled) also can be made into mineral wool. Slag for this purpose is remelted and then poured through an air stream or jet of steam or other gas to produce a spray of molten droplets; alternatively, the droplets can be formed by passing the melt through a perforated or fast spinning disc. The droplets elongate into long fibers that are collected and layered.

Steel furnace slag is cooled similarly to air-cooled blast furnace slag, has similar properties to it, and is used for many of the same purposes. Steel slags containing large amounts of dicalcium silicate are prone to expansion and commonly are cured in piles for some months to allow for this and for leaching out of lime.

Consumption

Data in this report are based on an annual U.S. Geological Survey (USGS) canvass of slag processors and relate to sales of processed slag rather than to the amount of slag processed by the same firms or to the actual production of slag by iron and steel companies. Processed slag is sold from stockpiles, and although most of the material is a byproduct of current or recent iron and steel production or is of imported material, some is material mined from old slag piles (slag banks) and reflects iron and steel production from plants now closed. In 2005, canvasses were sent to 27 companies, covering 131 processing sites, and at least partial data were received for 127 sites. By comparison, in 2004, canvasses were sent to 28 processing companies, covering 130 processing sites, and at least partial data were received for 126 sites. For both 2004 and 2005, the reported data account for about 98% of the gross tonnages listed in table 1. For both years, data on pelletized blast furnace slag have been withheld to avoid disclosing company proprietary data, but the quantities sold were very small. Prior to 2002, data for pelletized slag were presented combined with granulated slag under the term "Expanded slag."

In terms of tonnage, U.S. slag sales in 2005 continued to be dominantly of air-cooled blast furnace slag and steel slag (table 1). Air-cooled blast furnace slag sales totaled about 8.4 Mt in 2005, up by about 4% from the amount sold in 2004. In contrast, steel furnace slag sales declined by about 3% in 2005 to about 8.7 Mt. For all years, the sales data for air-cooled and steel furnace slags largely exclude material returned to the furnaces (and likewise exclude the weight of free metal recovered from the slag and returned to the furnace); data on these returns are very incomplete.

Air-cooled and steel furnace slags have a similar set of uses—mostly as aggregates for various applications (table 3). Because of potential expansion problems, steel slags find little use in applications requiring maintenance of a fixed volume (for example, concrete). Steel slags that contain a lot of free lime may be used as a soil conditioner. Most slags can be used as raw material for cement (clinker) manufacture (the slag contributes aluminum, calcium, iron, and silicon oxides) but steel slags have proven to be especially suitable for this use. Much of the use of steel slag as a raw material for clinker continued to be through the CemStar process, developed and patented by Texas Industries, Inc. (TXI) after researching higher valued uses for the slag produced by its subsidiary company Chaparral Steel Co. In December 2004, following the spinoff of Chaparral from TXI, it was announced that the CemStar patents and marketing rights had been sold to Edward C. Levy Co., a major steel furnace slag processing company (Edward C. Levy Co., 2005).

Even though the sales price data for air-cooled and steel slags contain a large component of estimates, it appears that the average selling prices of air-cooled and steel slag were essentially unchanged in 2005, although the upper end of the steel slag price range increased (table 2). Typically, the major factors affecting the sales volumes and prices of these slags include local competition from natural aggregates, the overall level of construction activity (particularly that for roads), and the existence of some long-term supply contracts. Because of generally low unit sales values, slags for aggregate applications cannot sustain long-distance transportation costs. Slag converted to mineral wool is mainly used for thermal insulation. Pelletized slag is primarily used for lightweight concrete aggregate; however, when finely ground, pelletized slag can be used as a supplementary cementitious material similar to GGBFS.

In terms of sales value, the slag market in the United States in 2005 remained dominated by granulated blast furnace slag, particularly GGBFS. In 2005, granulated slag accounted for almost 83% of the value of total blast furnace slag sales and 74% of total ferrous slag sales (table 1). The tonnage of granulated slag sold in 2005 increased by almost 10% to 4.5 Mt, of which about 3.8 Mt was GGBFS, and the rest was unground material. The value dominance of granulated slag reflects its high unit value relative to the other slag types (table 2), and this, in turn, reflects the ready market for GGBFS as a partial substitute for portland cement in ready-mixed concrete or mixed with portland cement to make finished blended cement (also for use in concrete). The unit value for granulated slag rose by more than 7% in 2005 and yet continued to sell at a 20% to 25% discount to portland cement. In concrete containing a proportion of GGBFS, hydration of portland cement releases the lime needed to fully activate the slag. Concretes incorporating GGBFS generally develop strength more slowly than concretes containing only portland cement but can have similar or even superior long-term strength, release less heat during hydration, have reduced permeability, and generally exhibit improved resistance to chemical attack. A small fraction of the unground granulated slag on the market has been sourced from old slag piles and lacks cementitious properties as a result of weathering; this material still has use in concrete (as a fine grain aggregate), but sells for much lower prices than those indicated for the cementitious material in table 2.

The USGS slag survey does not distinguish between granulated slag sold directly to cement companies and that sold directly to concrete companies, but data collected by the 2005 USGS cement survey indicate that cement producers themselves consumed about 15% of the total granulated slag sales (up from 8% in 2004). Sales in the United States of GGBFS under the designation "slag cement" are promoted by the Slag Cement Association (SCA), whose members accounted for much of the country's GGBFS output. The SCA reported sales by its members of 3.50 Mt of GGBFS in 2005, which is in close

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agreement with the USGS data (Slag Cement Association, 2006§[1]).

Foreign Trade

Imports of ferrous slags (excluding iron scales) totaled about 1.6 Mt in 2005, up by almost 63% from the 1.0 Mt imported in 2004. Granulated slag (mostly as unground material) imports totaled almost 1.1 Mt in 2005, compared with 0.76 Mt in 2004. For 2005, the average unit value (customs value) for imported granulated slag was $35.29 per metric ton, slightly lower than the $36.93 per ton average in 2004. By comparison, the cost, insurance, and freight (c.i.f.) value was $47.90 per ton in 2005 compared with $49.89 per ton in 2004. The difference in the c.i.f. values for the 2 years includes a modest ($0.35 per ton) decline in average shipping charges in 2005 compared with a $3.35 per metric ton shipping charge increase in 2004. Of the seven countries that supplied granulated slag in 2005, the leading sources were Italy (33%), Canada (24%), France (19%), and Japan (14%).

Outlook

Growth in consumption of ferrous slags as aggregate is expected to parallel growth trends for natural aggregates and is thus dependent on overall construction spending levels, especially spending in the public sector. Factors affecting increased use of slags relative to natural aggregates include the promotional efforts by the slag industry itself and slag availability. The generally declining trend in the U.S. output of iron and steel augurs for future supply constraints, especially as existing stockpiles get drawn down. The long-term availability of air-cooled slag is especially problematic given the continuing decline in the number of operating blast furnaces. Steel slag supplies are more assured, although an increasing fraction of this material will be from electric arc rather than basic oxygen furnaces.

[1]A reference that includes a section mark (§) is found in the Internet Reference Cited section.

The market for GGBFS is expected to continue to grow, in line with its performance advantages for concrete and efforts to reduce the environmental impacts of cement and concrete manufacture. Domestic output of granulated slag is limited by the fact that granulation cooling is currently installed at only five blast furnaces in the country, and one of these (at Weirton, WV) was shut down in mid-2005 following the purchase of the steel mill earlier in the year by Mittal Steel USA. Unless granulators are installed at other blast furnaces, future domestic growth of GGBFS production will be by grinding plants that rely on imported feed. Production of GGBFS at an import-fed grinding plant in Louisiana ceased in late August owing to damage sustained by the facility during Hurricane Katrina; repairs were continuing as of yearend and production was expected to resume in early 2006.

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TABLE 1
IRON AND STEEL SLAG SOLD OR USED IN THE UNITED STATES

(Million metric tons and million dollars)

	2004					2005				
	Blast furnace slag[1]			Steel	Total iron	Blast furnace slag[1]			Steel	Total iron
	Air-cooled	Granulated	Total[2]	furnace slag	and steel slag[2]	Air-cooled	Granulated	Total[2]	furnace slag	and steel slag[2]
Quantity[3]	8.1	4.1	12.2	9.0	21.2	8.4	4.5	12.9	8.7	21.6
Value[e, 4]	53	236	289	39	328	56	277	333	39	372

[e]Estimated.
[1]Excludes expanded (pelletized) slag to avoid disclosing company proprietary data. The quantities are very small (less than 0.1 unit).
[2]Data may not add to totals shown because of independent rounding.
[3]Quantities are rounded to reflect inclusion of some estimated data and to reflect inherent accuracy limitations of reported data.
[4]Values are rounded because of the inclusion of a large estimated component.

TABLE 2
SELLING PRICES FOR IRON AND STEEL SLAG IN THE UNITED STATES[1]

(Dollars per metric ton)

	2004		2005	
Slag type	Range	Average	Range	Average
Blast furnace slag:				
Air-cooled	1.54-17.35	6.58	2.76-17.50	6.57
Granulated[2]	22.05-71.65	61.49	17.63-88.18	66.04
Steel slag	0.22-7.89	4.32	0.22-12.85	4.45

[1]Underlying data contain a large component of estimates.
[2]Range shown is for material reported for use as a cementious additive in cement or concrete manufacture. Material at or near the low end of the range was sold in unground form.

TABLE 3
SALES OF FERROUS SLAGS IN THE UNITED STATES , BY USE[1]

(Percentage of total tons sold)

	2004			2005		
	Blast furnace slag[2]		Steel	Blast furnace slag[2]		Steel
Use	Air-cooled	Granulated	slag[3]	Air-cooled	Granulated	slag[3]
Ready-mixed concrete	20.4	--	--	16.1	--	--
Concrete products	3.5	--	--	5.2	--	--
Asphaltic concrete	20.4	--	12.9	16.7	--	15.6
Road bases and surfaces	32.3	--	63.5	34.0	--	53.0
Fill	4.9	--	9.6	11.1	--	10.5
Cementitious material	--	91.1	--	--	90.5	--
Clinker raw material	1.9	--	5.5	4.4	--	6.9
Miscellaneous[4]	4.2	--	2.9	9.0	--	2.3
Other or unspecified	12.4	8.9	5.6	3.5	9.5	11.7

-- Zero.
[1]Data contain a large component of estimates and are reliable to no more than two significant digits.
[2]Excludes expanded or pelletized slag; this material is generally sold as a lightweight aggregate.
[3]Steel slag use is based on the 77% of total tonnage sold in 2004 and the100% of total tonnage sold in 2005 (table 1) for which usage data were provided.
[4]Reported as used for railroad ballast, roofing, mineral wool, or soil conditioner.

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TABLE 4
PROCESSORS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 2005

Slag processing company	Plant location	Steel company serviced[1]	Slag and furnace types[2]					
			Blast furnace slag			Steel furnace slag		
			AC	GG	Exp	BOF	OHF	EAF
AMSI, Inc.	Holsopple, PA	North American Höganäs, Inc.						X
Barfield Enterprises, Inc.	La Place, LA	Bayou Steel Corp.						X
Do.	Lone Star, TX	Lone Star Steel Corp.						X
Beaver Valley Slag	Aliquippa, PA	Old slag pile site	X				X	
Do. (Thor Mill Services)	Roanoke, VA	Roanoke Electric Steel, Inc.						X
Beelman Truck Co.	Granite City, IL	U.S. Steel LLC	X					
Blackheart Slag Co.	Muscatine (Montpelier), IA	IPSCO Steel, Inc.						X
Border Steel, Inc.	El Paso, TX	Border Steel, Inc.						X
Buffalo Crushed Stone, Inc.	Woodlawn, NY	Old slag pile site	X					
Buzzi Unicem USA, Inc.	New Orleans, LA	Foreign[3]		X				
Civil & Marine, Inc.	Cape Canaveral, FL	do.		X				
Edward C. Levy Co.	Decatur (Trinity), AL	Nucor Steel Corp.						X
Do.	Butler, IN	Steel Dynamics Inc.						X
Do.	Columbia City, IN	do.						X
Do.	Crawfordsville, IN	Nucor Steel Corp.						X
Do.	Detroit, MI	Severstal North America, Inc.	X			X		
Do.	do.	U.S. Steel LLC	X			X		
Do.	Delta, OH	North Star-Bluescope Steel Inc.						X
Do.	Canton, OH	The Timken Co.						X
Do.	Huger, SC	Nucor Steel Corp.						X
Essroc Corp.	Middlebranch, OH	Miscellaneous domestic and foreign[3]		X				
Florida Rock Industries, Inc.	Tampa, FL	Foreign[3]		X				
Fritz Enterprises, Inc.	Fairfield, AL	U.S. Steel LLC	X			X		
Gerdau Ameristeel Corp.	Jacksonville, FL	Gerdau Ameristeel Corp.						X
Do.	Charlotte, NC	do.						X
Glens Falls-Lehigh Cement Co.	Cementon, NY	Foreign[3]		X				
Holcim (US) Inc.	Birmingham (Fairfield), AL	U.S. Steel LLC		X				
Do.	Gary, IN	do.		X				
Do.	Weirton, WV	Weirton Steel Corp.		X				
Lafarge North America Inc.	Joppa, IL	Mittal Steel USA		X				
Do.	South Chicago, IL	do.		X				
Do.	East Chicago, IN	do.		X	X			
Do.	Sparrows Point, MD	do.		X				
Do.	Cleveland (Cuyahoga Co.), OH[4]	do.	X					
Do.	Lordstown, OH	Old slag pile site		X				
Do.	McDonald, OH	do.	X					
Do.	Salt Springs (Youngstown), OH	do.	X					
Do.	Warren, OH	WCI Steel Inc.	X					
Do.	West Mifflin (Duquesne), PA	U.S. Steel LLC (ET Works)	X					
Do.	West Mifflin (Brown Reserve), PA	Old slag pile site	X					
Do.	Whitehall, PA	Foreign[3]		X				
Do.	Seattle, WA	do.		X				
Do.	Weirton, WV	Mittal Steel USA	X					
Lehigh Cement Co.	Evansville, PA	Foreign[3]		X				
Levy Co., Inc., The	Burns Harbor, IN	Mittal Steel USA	X			X		
Do.	East Chicago, IN	do.	X					
Do.	Gary, IN	U.S. Steel LLC	X	X				
Mountain Enterprises, Inc.	Ashland, KY[4]	AK Steel Corp.	X					
MultiServ	Birmingham, AL	Structural Metals Corp.						X
Do.	Blytheville, AR	Nucor Steel Corp.						X
Do.	Blytheville (Armorel), AR	Nucor-Yamato Steel Co.						X
Do.	Pueblo, CO	Rocky Mountain Steel Mills						X
Do.	Wilton (Muscatine), IA	IPSCO Steel, Inc.						X
Do.	Riverdale, IL	Mittal Steel USA				X		
Do.	East Chicago, IN	do.				X		
Do.	Indiana Harbor, IN	do.				X		
Do.	Pittsboro, IN	Steel Dynamics Inc.						X
Do.	Ghent, KY	Gallatin Steel Co.						X
Do.	do.	North American Stainless LP						X
Do.	Sparrows Point, MD	Mittal Steel USA	X			X		

See footnotes at end of table

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TABLE 4—Continued
PROCESSORS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 2005

Slag processing company	Plant location	Steel company serviced[1]	Slag and furnace types[2]					
			Blast furnace slag			Steel furnace slag		
			AC	GG	Exp	BOF	OHF	EAF
MultiServ—Continued:	Ahoskie (Cofield), NC	Nucor Steel Corp.						X
Do.	Canton, OH	Republic Engineered Products LLC						X
Do.	Mansfield, OH	AK Steel Corp.				X		
Do.	Warren, OH	WCI Steel Inc.				X		
Do.	Brackenridge, PA	Allegheny Ludlum Corp.						X
Do.	Braddock (Mon Valley), PA[5]	U.S. Steel LLC				X		
Do.	Butler, PA	AK Steel Corp.						X
Do.	Coatesville. PA	Mittal Steel USA						X
Do.	Koppel, PA	Koppel Steel Co. (NS Group, Inc.)						X
Do.	Latrobe, PA	Allegheny Ludlum Corp.						X
Do.	Natrona Heights, PA	do.						X
Do.	Steelton, PA	Mittal Steel USA						X
Do.	Midlothian, TX	Chaparral Steel Co.						X
Do.	Geneva (Provo), UT	Old slag pile site	X			X		
Do.	Seattle, WA	Nucor Steel Corp.						X
Recmix of PA, Inc.	Ghent, KY	North American Stainless, LP						X
Do.	Sarver (Brackenridge), PA	Allegheny Ludlum Corp.						X
Rinker Materials Corp.	Miami, FL	Foreign[3]		X				
St. Lawrence Cement, Inc.	Camden, NJ	do.		X				
St. Marys Cement, Inc.	Detroit, MI	do.		X				
Stein, Inc.	Alton, IL	Alton Steel Co.						X
Do.	Granite City, IL	U.S. Steel LLC				X		
Do.	Sterling, IL	Sterling Steel, Inc.						X
Do.	Ashland, KY[4]	AK Steel Corp.				X		
Do.	Cleveland, OH[4]	Mittal Steel USA				X		
Do.	Loraine, OH	Republic Engineered Products LLC	X			X		
Do.	Georgetown, SC	Georgetown Steel Corp.						X
Tube City-IMS, IMS Division	Axis, AL	IPSCO Steel, Inc.						X
Do.	Birmingham, AL	Nucor Steel Corp.						X
Do.	Tuscaloosa, AL	do.						X
Do.	Fort Smith, AR	MACSTEEL						X
Do.	Rancho Cucamonga, CA	TAMCO						X
Do.	Claymont, DE	CitiSteel USA, Inc.						X
Do.	Cartersville, GA	Gerdau Ameristeel Corp.						X
Do.	Wilton (Muscatine), IA	do.						X
Do.	Kankakee, IL	Nucor Steel Corp.						X
Do.	Peoria, IL	Keystone Steel & Wire Co.						X
Do.	Gary, IN	U.S. Steel LLC				X		
Do.	Portage, IN	Beta Steel Corp						X
Do.	Ashland, KY	Kentuckey Electric Steel LLC						X
Do.	Jackson, MI	MACSTEEL						X
Do.	Monroe, MI	Macsteel (Quanex, Corp.)						X
Do.	St. Paul, MN	Gerdau Ameristeel Corp.						X
Do.	Jackson, MS	Nucor Steel Corp.						X
Do.	Norfolk, NE	do.						X
Do.	Perth Amboy, NJ	Gerdau Ameristeel Corp.						X
Do.	Sayreville, NJ	do.						X
Do.	Auburn, NY	Nucor Steel Corp.						X
Do.	Marion, OH	Marion Steel Co.						X
Do.	McMinnville, OR	Cascade Steel Rolling Mills, Inc.						X
Do.	Middletown, OH	AK Steel Corp.	X			X		
Do.	Mingo Junction, OH	Wheeling Pittsburgh Steel Corp.	X			X		
Do.	Youngstown, OH	V&M Star						X
Do.	Sand Springs, OK	Sheffield Steel Corp.						X
Do.	Bethlehem, PA	Old slag pile site	X			X		
Do.	Braddock, PA[5]	U.S. Steel LLC				X		
Do.	Bridgeville, PA	Universal Stainless & Alloy Products Inc.						X
Do.	Midland, PA	Allegheny Ludlum Corp.						X
Do.	New Castle, PA	Ellwood Quality Steels Co.						X

See footnotes at end of table

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TABLE 4—Continued
PROCESSORS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 2005

Slag processing company	Plant location	Steel company serviced[1]	Slag and furnace types[2]					
			Blast furnace slag			Steel furnace slag		
			AC	GG	Exp	BOF	OHF	EAF
Tube City-IMS, IMS Division—Continued:	Park Hill (Johnstown), PA	Old slag pile site	X				X	
Do.	Pricedale, PA	do.				X		
Do.	Reading, PA	Carpenter Technology Corp.						X
Do.	Cayce, SC	SMI/CMC Steel Group						X
Do.	Darlington, SC	Nucor Steel Corp.						X
Do.	Jackson, TN	Gerdau Ameristeel Corp.						X
Do.	Knoxville, TN	do.						X
Do.	Beaumont, TX	do.						X
Do.	Jewett, TX	Nucor Steel Corp.						X
Do.	Longview, TX	LeTourneau Steel Group						X
Do.	Seguin, TX	SMI/CMC Steel Group						X
Do.	Plymouth, UT	Nucor Steel Corp.						X
Do.	Petersburg, VA	Chaparral Steel Co.						X
Do.	Saukville, WI	Charter Steel						X
Do.	Weirton, WV	Mittal Steel USA				X		
Uniserve LLC	Newport, AR	Arkansas Steel Association						X

[1]Currently operating iron and/or steel company. Company is not shown for old slag pile sites.

[2]Blast furnace slag type abbreviations: AC, air-cooled; GG, granulated; Exp, expanded. Steel furnace slag types: BOF, basic oxygen furnace; OHF, open hearth furnace; EAF, electric arc furnace.

[3]"Foreign" refers to the fact that the facility imports unground granulated blast furnace slag and grinds it onsite to make ground granulated blast furnace slag, commonly now referred to as "slag cement."

[4]For the air-cooled slag, Stein was responsible for the cooling, but the processing and marketing were handled by Lafarge North America Inc. (Cleveland, OH) and Mountain Enterprises, Inc. (Ashland, KY), respectively.

[5]Contract was transferred to Tube City IMS Corp. in mid-2005.

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Soda Ash

By Dennis S. Kostick

Domestic survey data and tables were prepared by Jeff Milanovich, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Soda ash, also known as sodium carbonate (Na_2CO_3), is an alkali chemical refined from the mineral trona or naturally occurring sodium carbonate-bearing brines (both referred to as natural soda ash), the mineral nahcolite (referred to as natural sodium bicarbonate, from which soda ash can be produced), or manufactured from one of several chemical processes (referred to as synthetic soda ash).

Despite the fact that most people have never heard of soda ash, it is an important industrial compound used to manufacture glass, chemicals, soaps and detergents, pulp and paper, and many other familiar consumer products. The United States has the world's largest natural deposit of trona and is the world's second ranked soda-ash-producing nation. U.S. natural soda ash is extremely competitive in world markets because the majority of the world output of soda ash is made synthetically, which is usually a more expensive process.

Production

Soda ash production and inventory data were collected by the U.S. Geological Survey (USGS) from monthly, quarterly, and annual voluntary surveys of the U.S. soda ash industry. A survey request was sent to each of the five soda ash companies, all of which responded, representing 100% of the total production data in this report (table 1).

For the third consecutive year, the United States was the world's second ranked soda-ash-producing nation. After more than a century of the United States leading in the world's production of soda ash, China overtook the United States in 2003, and it appears that China will continue to be the world's leader for the foreseeable future. U.S. production of natural soda ash from California and Wyoming in 2005 was 11 million metric tons (Mt), which was virtually identical with that of 2004. Based on about 14.5 Mt (16 million short tons) of total nameplate capacity, the U.S. soda ash industry operated at 76% of total capacity. This capacity utilization rate appears low because it includes the full nameplate capacity of 900,000 metric tons (t) (1 million short tons) for Solvay Chemicals, Inc.'s Parachute, CO, plant, which intentionally operated at reduced capacity during the year but was included in the industry total because nameplate capacity is based on the industry total as of December 31 of each year. In addition, the low capacity utilization rate resulted from idle capacity at OCI Chemical Corp. and FMC Wyoming Corp. plants of 816,000 t (900,000 short tons) and 953,000 t (1.05 million short tons), respectively. Approximately 2.7 Mt of nameplate capacity (2.98 million short tons), which represented about 19% of total industry nameplate capacity, was idled in 2005. This available capacity could be brought back online when market conditions improve. Rather than using nameplate capacity, the U.S. soda ash industry uses the term "effective capacity" because it disregards all idled or mothballed capacity. This results in higher capacity utilization percentages. Furthermore, individual effective capacity data are not publicly disclosed.

The U.S. soda ash industry consisted of five companies in 2005—four companies operating five plants in Wyoming that produced soda ash from underground trona ore and one in California that produced soda ash from sodium-carbonate-rich brines. One of the companies that operated a plant in Wyoming also operated one plant in Colorado, which was mothballed in September 2004 but continued sodium bicarbonate production using soda ash feedstock from the company's Wyoming soda ash facility. Stating that the demand for soda ash has increased, FMC Corp. restarted its Granger, WY, plant in June 2005, which it had acquired from Tg Soda Ash, Inc. in 1999 and had idled in May 2001. The company brought back onstream 276,000 t (250,000 short tons) of the 1.18 Mt (1.3 million short tons) of total nameplate capacity available (Chemical Week, 2005a).

Consumption

The USGS collects soda ash consumption data by end use on a quarterly basis from the marketing and sales departments of each company. Every effort has been made to categorize company sales within the correct end-use sector. Quarterly reports are often revised in subsequent quarters because of customer reclassifications or other factors. All U.S. soda ash companies responded to the quarterly surveys; data represented 100% of the total reported consumption data found in this report.

In 2005, U.S. apparent consumption of soda ash was 6.38 Mt; reported consumption, however, was 6.20 Mt (table 1). Reported consumption and apparent consumption do not necessarily correspond because reported consumption is actual sales, whereas apparent consumption is the calculated quantity available for domestic consumption based on balancing supply (production, imports, and inventory adjustments) with external demand (exports).

In 2005, U.S. apparent consumption and reported consumption varied by 180,000 t, which was attributed to a discrepancy in the export data that were used to derive consumption statistics. The two sources for export data were the U.S. Census Bureau, which reports exports upon departure from the U.S. ports, and the California and Wyoming soda ash producers, which consider shipments to be exported when their export association, American Natural Soda Ash Corp. (ANSAC), takes consignment of the product at the Wyoming plant sites. Transit times between the plant and port, which can take about 2 to 3 weeks before the cargo is actually exported, and carryover export inventories contribute to the discrepancy between reported and apparent consumption as well.

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In the domestic market, large-volume buyers of soda ash were primarily the major glass container manufacturers whose purchases were seasonal (more beverage containers are made in the second and third quarters for summertime beverage consumption). Soda ash sales to the flat glass sector depended more on the state of the economy because the leading uses of flat glass were in automobile manufacture and in residential housing and commercial building construction. These two major industrial sectors were especially sensitive to changing economic conditions, and soda ash sales follow trends in the two sectors. The distribution of soda ash by end use in 2005 was glass, 49%; chemicals, 27%; soap and detergents, 10%; distributors, 5%; miscellaneous uses, 4%; flue gas desulfurization and pulp and paper, 2% each; and water treatment, 1%.

Glass.—Glass manufacture represented about 50% of domestic soda ash consumption; container, 48%; flat, 37%; fiber, 9%, and specialty, 6%. Glass containers are made for beverages (beer, carbonated, and noncarbonated drinks), chemical and household products, food, liquor, medical products, and toiletries and cosmetics. In 2004, about 35 billion glass containers were manufactured, of which 75% were for beverages (about 50% were beer bottles) and the remainder mostly were for food containers. Nearly 2.13 Mt, or 22%, of glass containers were recycled (Waste Age, 2005).

Chemicals.—Soda ash is used to manufacture many sodium-base inorganic chemicals, including sodium bicarbonate, sodium chromates, sodium phosphates, and sodium silicates.

Soaps and Detergents.—Detergents were the third ranked use of soda ash. Soda ash was used as a builder to emulsify oil stains, to reduce the redeposition of dirt during washing and rinsing, to provide alkalinity for cleaning, and to soften laundry water. In addition, soda ash was a component of sodium tripolyphosphate (STPP), another major builder in detergent formulations. Soda ash consumption has been decreasing because phosphatic detergents can contribute to eutrophication, which is an environmental concern. Many regions of the Nation adopted phosphate limitations or bans, affecting about 40% of the U.S. population. A strong U.S. economy boosted demand for industrial and institutional cleaners and automatic dishwashing detergents in the past several years. New technology incorporating enzymes in dishwashing detergents and a move toward liquid cleansers, however, may adversely affect STPP consumption in the future.

In response to the environmental concern that cardboard detergent packaging contributes to the volume of landfill waste, detergent manufacturers changed formulations to make compact and superconcentrated products. These reformulations required sodium silicates and synthetic zeolites, which are made from soda ash. Liquid detergents, which do not contain any soda ash, competed with powdered detergents and commanded about 50% of the household laundry detergent market in 2005.

Stocks

Yearend 2005 stocks of dense soda ash in domestic plant silos, warehouses, terminals, and on teamtracks amounted to 243,000 t. Producers indicated that a potential supply problem could exist if inventories fell below 180,000 t. Most consumers of soda ash did not have the storage facilities to accommodate large quantities of soda ash and had to rely on suppliers to provide the material on a timely basis.

Prices

The average annual value for bulk, dense natural soda ash, free-on-board (f.o.b.) Green River, WY, and Searles Valley, CA, was $88.39 per metric ton ($80.19 per short ton), which was 26% more than that of 2004. The value is not a "price," but rather the value of the combined revenue of California and Wyoming bulk, dense soda ash sold on an f.o.b. plant basis at list, spot, or discount prices, on long-term contracts, and for export, divided by the quantity of soda ash sold. Only merchant soda ash is used to derive the annual value; therefore, no soda ash for value-added products or soda liquors is included. The list prices quoted in trade journals or by producers differed from the annual average values reported to and by the USGS.

High energy and transportation costs caused soda ash prices to soar during 2005. In addition, list and off-list prices for 2004 increased, but not every soda ash producer achieved these increases because several older, multiyear contracts with price caps were still not renewable. To help offset the escalating energy and transportation costs, the domestic soda ash industry was forced to consider raising prices in 2005. Searles Valley Minerals, Inc. and FMC each announced a $15 per short ton price increase effective May 1 and June 1, respectively. General Chemical (Soda Ash) Partners followed with a $30 price increase for its list and off-list prices. Since June 2004, General Chemical had announced a cumulative price increase of $60 per short ton. Finally, Solvay Chemicals announced in June an additional $15 per short ton increase in its off-list price of soda ash effective immediately or as contracts permitted (Chemical Week, 2005c). OCI Chemical delayed any increase in its prices at that time but did raise its f.o.b. Wyoming list price for bulk, dense soda ash to $155 per short ton effective September 1 (OCI Chemical Corp., 2005§[1]).

On September 15, FMC announced that, effective October 1 or as contracts permitted, it would increase off-list prices by $15 per short ton for all grades of soda ash and that its list price, f.o.b. Green River and Granger would be $155 per short ton (FMC Corp., 2005§). The energy surcharge and freight policy changes initiated in 2004 would remain in full effect for 2005 and beyond.

Because the price of natural gas remained high in 2005, all the producers maintained an energy surcharge on soda ash sales. Depending on the company, the surcharges were adjusted either monthly [based on the last quoted New York Mercantile Exchange (NYMEX) Henry Hub closing price for the next forward month] or quarterly (based on the 3-month forward average NYMEX gas price using the closing price as of the 15th of the month prior to the beginning of each calendar quarter). The surcharges would be in effect as long as the price of natural gas was between $5.00 and $8.00 per million British thermal units (Solvay Chemicals, Inc., 2004§).

[1]References that include a section mark (§) are found in the Internet References Cited section.

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By yearend 2005, the list price for Wyoming bulk, dense soda ash had increased to $155 per short ton, f.o.b. plant. Searles Valley Minerals in California raised its f.o.b. list price to $180 per short ton for bulk, dense soda ash.

Foreign Trade

U.S. soda ash exports for 2005 were 4.48 Mt according to the U.S. Census Bureau. Industry sources indicated that there may be some unreported soda ash shipments that were exported but were not included in the U.S. Census Bureau statistics. Using the Journal of Commerce's Port Import-Export Reporting Service (PIERS) and data provided by the soda ash producers, there appeared to be at least 180,000 t of additional soda ash exports that needed to be added to the 2005 export totals, which were shipped primarily to Argentina and Venezuela through the Long Beach, CA, and Port Arthur, TX, customs districts. The USGS adjusted the data to account for the discrepancies. Therefore, the 2005 U.S. soda ash export total was 4.68 Mt, which was a record high and represented about 43% of U.S. soda ash production.

In 2005, U.S. exports to 41 countries, on a regional basis, were as follows: Asia, 29%; North America and South America, 27% each; Europe, 10%; the Middle East, 3%; Oceania, 3%; Africa, 1%; and Central America and the Caribbean, about 1% (table 6). The average free alongside ship value was $136.75 per metric ton in 2005 compared with $110.06 per ton in 2004. Although the data in tables 1 and 6 are rounded to three significant digits, the unit values listed in table 6 are based on the unrounded statistics. The top 10 countries, representing 70% of total United States soda ash exports, in decreasing order and percentage of total were Mexico, 17%; Brazil, 10%; Canada, 9%; Japan and Indonesia, 6% each; Venezuela and Chile, 5% each; and Taiwan, the Republic of Korea, and Argentina, 4% each. About 47% of all United States soda ash exports went through the Columbia-Snake River customs district in Idaho, Oregon, and Washington; the Port Arthur customs district was the second ranked customs district with 18% of the total, and the Laredo, TX, customs district was third, with 15% of the total (table 5).

Imports of soda ash increased slightly to 8,200 t. The majority of imports historically came from Canada, where General Chemical had operated a synthetic soda ash plant in Amherstburg, Ontario, until April 2001. The facility produced dense and light soda ash, the majority of which was light soda ash exported to the United States. In 2005, about 32% of soda ash imports was from the United Kingdom, and 25% was from Mexico. The remainder of imports was from Belgium, China, France, Germany, India, Italy, Japan, and Romania. About 360 t of soda ash was reportedly imported from the Dominican Republic, which does not produce soda ash. [This material either was in the wrong category (mislabeled) or was transshipped from another source.] The average cost, insurance, and freight value of imported soda ash was $299.96 per ton, and the customs value was $244.35 per ton.

World Industry Structure

Soda ash is a mature commodity in which consumption tends to grow in proportion to population and gross domestic product growth rates. For this reason, the leading customers of soda ash were, for the most part, developed nations that have lower growth rates compared with developing countries. The developing nations tend to have higher soda ash demands and higher growth rates. Although the production and consumption quantities varied among the countries, the end-use patterns were basically the same—glass, chemicals, and detergents were the major sectors.

Nine countries produced more than 1 million metric tons per year (Mt/yr). They were, in descending order, China, the United States, Russia, Germany, India, Poland, France, Italy, and the United Kingdom. Bulgaria, Romania, and Ukraine had production installations that were rated at about 1 Mt/yr; adverse economic conditions, however, caused these nations to produce below their facilities' design capacities. Recent acquisitions or joint ventures with major European soda ash producers that have soda ash manufacturing expertise should reverse this situation in the next few years. In 2005, world soda ash production was estimated to be 41.9 Mt, which was a 4% increase compared with that of 2004.

World Review

Argentina.—After many years of planning and setbacks, Alcalis de la Patagonia SA came onstream in April with its synthetic soda ash plant at San Antonio Oeste, Rio Negro. Although the plant had a design capacity of 250,000 metric tons per year (t/yr), it was scheduled to produce about 70,000 t the first year. The plant will supply soda ash primarily to customers in Brazil (Noticias Net, 2005§).

India.—Tata Chemicals Ltd. announced plans to expand soda ash production capacity at its plant at Mithapur in Gujarat. The $34.4 million expansion will increase production capacity to 1 Mt/yr from 875,000 t/yr with completion scheduled for March 2006 or earlier. The decision to increase capacity was based on the belief that United States soda ash exports to Asian markets would become less competitive as transportation rates increase and China's shortage of salt for synthetic soda ash manufacture continues (Chemical Market Reporter, 2005).

Pakistan.—ICI Pakistan, Ltd. announced it would invest $15 million to increase soda ash production capacity at its Khewra facility. The plant would expand by 50,000 t/yr to 225,000 t/yr of soda ash. The facility accounted for about 75% of the country's soda ash requirements (Chemical Week, 2005b).

Romania.—In December, Gujarat Heavy Chemicals Ltd. of India acquired a 65% share of SC Bega Upsom SA, the Romanian synthetic soda ash producer, for $19.5 million. Gujarat Heavy Chemicals owned and operated a 525,000-t/yr synthetic soda ash plant in Sutrapada, India; the Romanian plant at Ocna Mures had capacity of 200,000 t/yr (Financial Express, The, 2005§).

United Kingdom.—In November, Tata Chemicals purchased a 63.5% majority share for $113 million of Brunner Mond Ltd. of the United Kingdom. The sale from Wayland Investments Ltd. and Barclays Bank included the two synthetic soda ash plants in Northwich, Cheshire, a synthetic soda ash plant in Delfzijl, Netherlands, and the natural soda ash facility at Lake Magadi, Kenya. Tata Chemicals became the third ranked soda

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ash producer in the world with a combined capacity of 3 Mt/yr (Trona Patch Times, 2005).

Outlook

After surpassing the United States as the world's leading soda ash producer for the third consecutive year, China continued to add new capacity and increase existing capacity at several of its plants despite escalating production costs. China imported a large quantity of fuel to satisfy the energy requirements of many of its energy-intensive industries, one of which was its synthetic soda ash industry. Higher energy costs and the rising cost of importing salt are expected to cause the price of Chinese soda ash to rise in 2006, and could that benefit the U.S. soda ash industry. Although Chinese soda ash consumption appears to be stabilizing, it is unclear how long China will continue to increase production of soda ash. The United States soda ash industry may expect to continue to encounter intense competition from China in some of the Asian markets.

Three dominant groups have survived to become the world leaders in soda ash—Solvay S.A. of Belgium, ANSAC of the United States (which represents all five domestic producers), and Chinese producers. Because the glass container sector is the leading soda-ash-consuming sector, the demand for soda ash for glass containers may decline as consumers slowly accept their food and beverages packaged in the newer polyethylene terephthalate (PET) containers.

The outlook for United States soda ash for the next 5 years is optimistic despite competition from Chinese soda ash producers. Domestic soda ash production is expected to grow by about 0.5% per year, and growth in world demand is forecast to range from 2.0% to 2.5% per year for the next several years. Asia and South America remain the likeliest areas for increased soda ash consumption in the near future.

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TABLE 1
SALIENT SODA ASH STATISTICS[1]

(Thousand metric tons and thousand dollars except average annual value)

	2001	2002	2003	2004	2005
United States:					
Production:					
Soda ash:[2]					
Quantity	10,300	10,500	10,600	11,000	11,000
Value	773,000	784,000	765,000	770,000	968,000
Value, average annual:					
Per short ton	$67.79	$68.00	$65.21	$63.75	$80.19
Per metric ton	$74.73	$74.96	$71.88	$70.27	$88.39
Wyoming trona	15,400	15,100	15,500	16,500	17,000
Exports:					
Quantity	4,090	4,250	4,450	4,670	4,680
Value	487,000	500,000	515,000	514,000	640,000
Imports for consumption:					
Quantity	33	9	5	6	8
Value	4,070	2,000	1,510	1,880	2,460
Stocks, December 31, producers'	226	222	330	338	243
Consumption:					
Apparent	6,310	6,250	6,090	6,290	6,380
Reported	6,380	6,430	6,270	6,260	6,200
World, production[e]	35,700 r	37,200 r	38,400 r	40,300	41,900

[e]Estimated. [r]Revised.

[1]Data are rounded to no more than three significant digits, except value per ton.

[2]Natural only; soda liquors and purge liquors are withheld to avoid disclosing company proprietary data.

TABLE 2
U.S. PRODUCERS OF SODA ASH IN 2005

(Million short tons unless otherwise noted)

Company	Plant nameplate capacity	Plant location	Source of sodium carbonate
FMC Wyoming Corp.:			
Granger[1]	1.30	Granger, WY	Underground trona.
Green River[2]	3.55	Green River, WY	Do.
General Chemical (Soda Ash) Partners[3]	2.80	do.	Do.
OCI Chemical Corp.[4]	3.10	do.	Do.
Searles Valley Minerals, Inc.[5]	1.45	Trona, CA	Dry lake brine.
Solvay Chemicals, Inc.:[6]			
Green River	2.80	Green River, WY	Underground trona.
Parachute[7]	1.00	Parachute, CO	Underground nahcolite.
Total	16.00		
Total million metric tons	14.50		

[1]Tg Soda Ash Inc. was sold to FMC Wyoming Corp. in July 1999.

[2]Formed joint venture (20%) in February 1996 with Sumitomo Corp. and Nippon Sheet Glass Co., Ltd., both of Japan.

[3]A joint venture between General Chemical Corp. (75%), Owens-Illinois, Inc. [acquired Australian Consolidated Industries International (ACI) in 1998] (25%). Tosoh Wyoming Inc. of Japan, which purchased part of ACI's 24% share in June 1992, sold its shares to General in August 2005.

[4]Rhône-Poulenc Basic Chemicals Co. of France sold its 51% share to Oriental Chemical Industries Chemical Corp. (OCI) of the Republic of Korea on February 29, 1996; Anadarko Petroleum Corp. (acquired Union Pacific Resources in 2000) owns 49%. An 800,000-short-ton expansion, brought onstream in November 1998, increased plant capacity to 3.1 million short tons; however, the company planned to take 900,000 short tons out of service temporarily for equipment refurbishment.

[5]IMC Global, Inc. acquired North American Chemical Co. in April 1998; operation sold in 2004 to Sun Capital Partners, Inc. (80.1%) with IMC retaining a 19.9% share.

[6]Solvay Soda Ash Joint Venture is owned by Solvay S.A. of Belgium (80%) and Asahi Glass Co. of Japan (20%), which became a partner in February 1990. Capacity increase of 272,000 metric tons (t) (300,000 short tons) installed December 1995 and 454,000 t (500,000 short tons) in October 2000. Company name changed to Solvay Chemicals, Inc. in 2003.

[7]Came onstream October 2000. A joint venture with Williams Sodium Products Co. [a wholly owned subsidiary of The Williams Companies, Inc. (60%) and American Alkali, Inc. (40%)]. Operation sold to Solvay America, Inc. on September 10, 2003. Soda ash plant idled.

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TABLE 3
REPORTED CONSUMPTION OF SODA ASH IN THE UNITED STATES, BY END USE, BY QUARTER[1]

(Thousand metric tons)

SIC[2] code	End use	2004	2005 First quarter	2005 Second quarter	2005 Third quarter	2005 Fourth quarter	2005 Total
32	Glass:						
3221	Container	1,520	363	372	374	351	1,460
3211	Flat	1,130	269	289	291	277	1,130
3296	Fiber	283	69	72	70	74	284
3229	Other	188	43	46	47	42	179
	Total	3,120	744	779	782	745	3,050
281	Chemicals	1,620	405	432	428	416	1,680
284	Soaps and detergents	661	163	158	154	149	624
26	Pulp and paper	90	22	23	22	22	90
2899	Water treatment[3]	82	20	21	17	20	78
	Flue gas desulfurization	128	34	33	39	36	141
	Distributors	300	75	74	72	70	290
	Other	255	72	54	59	56	241
	Total domestic consumption[4]	6,260	1,540	1,570	1,570	1,510	6,200
	Exports[5]	4,610	1,220	1,280	1,190	1,180	4,870
	Canada	332	98	96	94	104	393
	Total industry sales[6]	10,900	2,750	2,860	2,760	2,690	11,100
	Total sales from plants	11,500	2,760	2,860	2,790	2,790	11,200
	Total production	11,000	2,680	2,790	2,770	2,720	11,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Standard industrial classification.
[3]Includes soda ash equivalent from soda liquors and purge liquors sold to powerplant for water treatment. Sales of mine water are excluded.
[4]Imports reported by the producer/importer have been distributed into appropriate end-use categories listed above.
[5]As reported by producers. Includes Canada. Data may not necessarily agree with those reported by the U.S. Census Bureau for the same periods.
[6]Represents soda ash from domestic origin (production and inventory changes) and imports and exports. Includes soda ash sold by coproducers and distributed by purchasers into appropriate end-use categories.

TABLE 4
SODA ASH YEAREND PRICES

(Dollars per short ton)

	2004	2005
Sodium carbonate (soda ash):		
Dense, 58% Na_2O 100-pound, paper bags, carlot, works, free on board	152.00-159.00	152.00-159.00
Bulk, carlot, same basis, tons	127.00-135.00	127.00-135.00
Light, 100-pound, paper bags, carlot same basis	188.00-215.00	188.00-215.00
Bulk, carlot, same basis, tons	176.00	176.00

Source: Current prices of chemicals and related materials, Chemical Market Reporter, January 3, 2005; January 9, 2006.

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TABLE 5
REGIONAL DISTRIBUTION OF U.S. SODA ASH EXPORTS, BY CUSTOMS DISTRICTS, IN 2005[1]

(Metric tons)

Customs districts	North America	Central America	South America	Caribbean	Europe	Middle East	Africa	Asia	Oceania	Total	Percentage of total
Atlantic:											
Baltimore, MD	--	--	--	--	1,830	--	--	--	--	1,830	(2)
Charleston, SC	--	--	--	--	--	--	--	6	--	6	(2)
Miami, FL	--	28	5	5	--	--	--	--	--	38	(2)
New York, NY	--	--	--	--	1,440	--	--	4	1	1,450	(2)
Norfolk, VA	--	--	--	--	324	--	--	--	--	324	(2)
Tampa, FL	--	--	149	--	--	--	--	--	--	149	(2)
Gulf:											
Houston-Galveston, TX	--	6	100	2,970	597	--	--	--	--	3,670	(2)
Port Arthur, TX	--	--	628,000	--	144,000	--	49,800	--	--	821,000	18
Pacific:											
Columbia-Snake River, ID-OR-WA	--	36,100	349,000	--	228,000	125,000	--	1,350,000	130,000	2,220,000	47
Los Angeles, CA	--	--	267,000	--	64,800	--	--	5,860	6,020	344,000	7
San Diego, CA	31,500	4,400	9,580	--	19,400	--	--	--	--	64,900	1
Seattle, WA	11,100	--	--	--	--	--	--	298	--	11,400	(2)
North Central:											
Chicago, IL	--	--	--	--	--	--	--	25	--	25	(2)
Cleveland, OH	180	--	--	--	--	--	--	--	--	180	(2)
Detroit, MI	344,000	--	--	--	169	--	--	--	--	344,000	7
Duluth, MN	82	--	--	--	--	--	--	--	--	82	(2)
Great Falls, MT	56,500	--	--	--	--	--	--	--	--	56,500	1
Pembina, ND	8,120	--	--	--	--	--	--	--	--	8,120	(2)
Northeast:											
Buffalo, NY	5,820	--	--	--	--	--	--	--	--	5,820	(2)
Ogdensburg, NY	3,460	--	--	--	49	--	--	--	--	3,510	(2)
St. Albans, VT	375	--	--	--	--	--	--	--	--	375	(2)
Southwest:											
El Paso, TX	69,600	--	--	--	--	--	--	--	--	69,600	1
Laredo, TX	709,000	--	--	--	--	--	--	--	--	709,000	15
Unknown	11,300	--	--	--	--	--	--	--	--	11,300	(2)
Total	1,250,000	40,500	1,250,000	2,980	460,000	125,000	49,800	1,360,000	136,000	4,680,000	100
Percentage of total	27	1	27	(2)	10	3	1	29	3	100	XX

XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau, as adjusted by the U.S. Geological Survey using data and information from the Journal of Commerce PIERS trade service and industry sources.

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TABLE 6
U.S. EXPORTS OF SODA ASH, BY COUNTRY[1]

Country	2004 Quantity (thousand metric tons)	2004 Value[2] (thousands)	2004 Unit value	2005 Quantity (thousand metric tons)	2005 Value[2] (thousands)	2005 Unit value
Argentina	190	$24,300	$128	166	$24,600	$148
Aruba	3	277	110	3	327	110
Australia	111	12,800	115	100	13,100	131
Belgium	179	22,000	123	150	18,600	124
Belize	--	--	--	(3)	8	276
Brazil	289	35,600	123	450	69,200	154
Canada	403	33,100	82	441	50,800	115
Chile	225	28,900	128	234	31,500	134
China	166	12,500	75	95	12,000	126
Colombia	94	13,100	140	114	17,500	153
Costa Rica	6	915	153	17	2,790	169
Dominican Republic	(3)	7	111	--	--	--
Ecuador	11	1,420	126	10	1,350	142
Finland	(3)	13	249	(3)	19	284
France	79	8,250	104	32	3,970	123
Germany	1	102	110	--	--	--
Grenada	--	--	--	(3)	3	600
Guatemala	18	2,810	156	18	2,800	155
Indonesia	327	32,400	99	266	38,200	144
Ireland	(3)	4	109	(3)	27	108
Israel	(3)	3	109	--	--	--
Italy	(3)	10	319	(3)	81	281
Japan	410	43,700	107	302	38,900	129
Korea, Republic of	230	23,200	101	188	27,100	144
Malaysia	109	12,200	112	114	17,300	151
Mexico	614	76,000	124	811	105,000	129
Netherlands	90	10,800	120	102	16,100	157
Netherlands Antilles	(3)	25	448	--	--	--
New Zealand	35	3,990	114	36	4,640	128
Pakistan	5	467	93	(3)	8	2,000
Panama	4	479	120	6	876	146
Peru	25	3,410	134	33	4,780	147
Philippines	71	7,560	106	51	7,950	155
Poland	(3)	62	341	(3)	41	171
Portugal	33	3,410	105	14	1,760	122
Russia	(3)	49	132	2	251	113
Saudi Arabia	128	12,000	94	96	11,200	117
South Africa	44	4,940	112	50	7,150	144
Spain	125	13,600	109	158	19,900	126
Suriname	(3)	7	1,715	--	--	--
Taiwan	184	18,600	101	195	27,100	139
Thailand	189	18,600	99	142	21,600	152
United Arab Emirates	39	3,180	82	29	3,400	116
United Kingdom	8	884	114	(3)	3	3,000
Venezuela	212	28,000	132	247	38,200	154
Vietnam	10	830	83	3	596	203
Total	4,670	514,000	110	4,680	640,000	137

-- Zero.

[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.
[2]Free alongside ship value.
[3]Less than ½ unit.

Source: U.S. Census Bureau, as adjusted by the U.S. Geological Survey using data and information from the Journal of Commerce Port Import-Export Reporting Service and industry sources.

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TABLE 7
U.S. PRODUCTION OF SODIUM COMPOUNDS, BY MONTH[1]

(Thousand metric tons)

	2004		2005	
	Soda ash	Wyoming trona[2]	Soda ash	Wyoming trona[2]
January	857	1,310	925	1,440
February	852	1,330	858	1,350
March	937	1,500	894	1,410
April	913	1,430	928	1,360
May	935	1,340	931	1,510
June	894	1,240	932	1,550
July	963	1,400	955	1,550
August	929	1,490	893	1,380
September	907	1,420	923	1,480
October	933	1,400	898	1,320
November	902	1,370	895	1,310
December	936	1,210	922	1,360
Total	11,000	16,500	11,000	17,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes solution-mined trona.

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TABLE 8
SODA ASH: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Thousand metric tons)

Country[3]	2001	2002	2003	2004	2005
Argentina	--	--	--	--	70
Australia	300	300	300	300	300
Austria	150	150	150	150	150
Bosnia and Herzegovina	37 r, 4	-- r	12 r, 4	11 r	11
Botswana[5]	251 4	283 4	309 4	263 r, 4	250
Brazil	200	200	200	200	200
Bulgaria	800	800	800	800	800
Canada	300	300	300	300	300
Chad	12	12	12	12	12
China	9,144 4	10,330 4	11,336 4	12,668 4	14,210 4
Egypt	50	50	50	50	50
Ethiopia	8 4	4 4	4 4	6 r, 4	7
France	1,000	1,000	1,000	1,000	1,000
Germany	1,500 r	1,500 r	1,500 r	1,500 r	1,500
India	1,500	1,500	1,500	1,500	1,500
Iran	120	120	120	130 r	130
Italy	1,000	1,000	1,000	1,000	1,000
Japan	461 4	410	400	400 r	400
Kenya[5]	298 4	304 4	353 4	356 4	360 4
Korea, Republic of	310	310	310	310	310
Mexico	290	290	290	290	290
Netherlands	400	400	400	400	400
Pakistan	230	230	230	230	230
Poland	1,062 4	1,054 4	1,110 r, 4	1,167 r, 4	1,115 4
Portugal	150	150	150	150	150
Romania	448	454	407 r	401 r	410
Russia	2,370	2,400	2,400	2,600	2,600
Spain	500	500	500	500	500
Taiwan	140	140	140	140	140
Turkey	640	825 r, 4	835 r, 4	846 r, 4	850
Ukraine	650	678	650	650	700
United Kingdom	1,000	1,000	1,000	1,000	1,000
United States[5]	10,300 4	10,500 4	10,600 4	11,000 4	11,000 4
Total	35,700 r	37,200 r	38,400 r	40,300	41,900

rRevised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through April 18, 2006. Synthetic unless otherwise specified.

[3]In addition to the countries listed, Tanzania may produce soda ash for local consumption; available general information is inadequate for the formulation of reliable estimates of output levels.

[4]Reported figure.

[5]Natural only.

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STONE, CRUSHED

By Jason Christopher Willett

Domestic survey data and tables were prepared by Susan M. Weaver, Evangeline J. Hemphill, and Richard H. Kraft, statistical assistants.

A total 1.69 billion metric tons (Gt) of crushed stone was produced for consumption in the United States in 2005, a 59-million-metric-ton (Mt), or 3.6%, increase compared with the total production of 2004. This tonnage represents the highest production level ever recorded in the United States. The value of the total crushed stone produced in the United States in 2005 was $12.1 billion, a 22.4% increase compared with the revised 2004 total (table 1).

About 70.1% of crushed stone production continued to be limestone and dolomite followed by, in descending order of tonnage, granite, traprock, sandstone and quartzite, miscellaneous stone, marble, calcareous marl, shell, slate, and volcanic cinder and scoria (table 2).

Foreign trade of crushed stone remained small. Exports decreased in 2005 to 1.26 Mt, or by 1.6%, compared with the total of 1.28 Mt in 2004, and the value decreased to $50.5 million, or by 7.4%, compared with the total of $54.5 million in 2004 (table 26).

Imports of crushed stone, including calcium carbonate fines, increased by 12.6% to 21 Mt, and the value increased by 8.7% to $194 million compared with the 2004 totals (table 27). Apparent domestic consumption of crushed stone, which is defined as production for consumption (sold or used) plus imports minus exports, increased to 1.71 Gt, or by 3.7%, compared with the total of 1.64 Gt in 2004 (tables 1, 26-27).

Stone is one of the most accessible natural resources of the Earth and one of the fundamental building blocks of our society. It has been used from the earliest times of our civilization for a variety of uses that have increased in number and complexity with time and technological progress. Today, in its crushed form, stone is a major basic raw material for the construction industry, as well as agriculture, and other industries that use complex chemical and metallurgical processes. Despite the relatively low, but increasing, unit value of its basic products, the crushed stone industry is a major contributor to and an indicator of the economic well-being of the Nation. Construction aggregates are defined as the combination of crushed stone and construction sand and gravel. The construction sand and gravel industry is reviewed in a separate chapter, and both mineral commodities should be included in any review of the national, State, or local aggregates industry.

Production

Domestic production data for crushed stone were derived by the U.S. Geological Survey (USGS) from voluntary surveys of U.S. producers. In 2005, a total of 1,163 companies produced or sold crushed stone from 3,114 operations with 3,171 quarries and 184 sales/distribution sites. Of the 3,114 active operations, 2,303 operations reported their production or sales to the USGS, and their total production was 1.38 Gt, or 82.0% of the U.S. total. Of the 2,303 reporting operations, 833 operations with 753 quarries and 83 sales yards owned by 91 companies did not report a breakdown by end use. Their total production was 540 Mt, or 32.1% of the U.S. total, and is included in table 13 under "Unspecified, reported" uses.

Production of the nonresponding quarries was estimated using employment data provided by the Mine Safety and Health Administration. The estimated output of 811 nonrespondent operations with 859 quarries and 7 sales yards owned by 556 companies was 304 Mt, or 18.0% of the U.S. total, and is included in table 13 under "Unspecified, estimated" uses.

A total of 184 sales yards in 31 States was active in 2005, a decrease from 187 sales yards in 31 States in 2004. The total output sold through the sales/distribution yards was 73.6 Mt. Information regarding the number of active operations, active quarries, type of processing plants, and number of sales yards by State is provided in table 25.

Crushed stone was produced in every State except Delaware. Starting with 2005, Delaware's production is included in the U.S. total because of sales yards that operated in the State. The 10 leading producing States were, in descending order of tonnage, Texas, Florida, Pennsylvania, Missouri, Virginia, Georgia, Illinois, Ohio, North Carolina, and Tennessee. Their combined production increased by 4.8% and was about 909 Mt, or 53.9% of the national total.

There are 84 underground mines included in the total number of active operations, and they produced 77.2 Mt of crushed stone in 2005. Active underground mines were located in 18 States. The five leading States were, in descending order of tonnage, Missouri, Kentucky, Illinois, Iowa, and Pennsylvania. Their combined production was 62.4 Mt, or 80.8% of the total U.S. crushed stone produced underground.

A total of 743 operations was either idle or presumed to have been idle in 2005 because no production report was received and no employment information was available to estimate their production. Since the 2004 survey, 220 operations have been closed. Most of the idle or closed operations were small, temporary quarries, some of which were operated by State or local governments. Operations in U.S. territories are not included in the above count.

Of the total 1.69 Gt of crushed stone produced for consumption in the United States in 2005, 1.2 Gt, or 70.1%, was limestone and dolomite; 263 Mt, or 15.6%, was granite; and 130 Mt, or 7.7%, was traprock. The remaining 112 Mt, or 6.7%, was shared, in descending order of tonnage, by sandstone and quartzite (3.3%), miscellaneous stone (1.8%), marble (0.5%), calcareous marl (0.3%), shell (0.3%), slate (0.2%), and volcanic cinder and scoria (0.2%) (table 2).

A comparison of the four geographic regions of the United States indicates that the production for consumption of crushed

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stone increased in three of four regions in 2005 (table 3). The largest percent increases were in the South (6.8%) and the West (3.5%) compared with production in 2004. In 2005, the South continued to lead the Nation in the production of crushed stone with 837 Mt, or 49.6% of the total, followed by the Midwest with 464 Mt, or 27.5%. The South and Midwest regions, composing 28 of the 48 continuous States, accounted for 77% of the total U.S. crushed stone output. The Northeast region recorded a decrease of 2.7% in the production for consumption of crushed stone.

A comparison of the nine geographic divisions of the United States indicates that, in 2005, the production for consumption of crushed stone increased in seven divisions compared with 2004. The major increases in percentages were recorded in the West South Central (11.4%), South Atlantic (6.3%), and Pacific (5.0%) divisions. Of the nine geographic divisions, the South Atlantic led the Nation in the production of crushed stone with 438 Mt, or 26.0% of the U.S. total, followed by the East North Central with 284 Mt, or 16.8%, and the West South Central with 223 Mt, or 13.2% (table 3). Decreases in production for consumption of crushed stone were recorded in the Middle Atlantic (3.5%) and East North Central (0.2%) divisions.

The leading U.S. producing companies in 2005 were, in descending order of tonnage, Vulcan Materials Co.; Martin Marietta Aggregates; Hanson Building Materials America, Inc.; Oldcastle, Inc./Materials Group; Lafarge North America Inc.; Rinker Materials Corp.; CEMEX, Inc.; Rogers Group, Inc.; Holcim/Aggregate Industries; and Florida Rock Industries, Inc. The combined production of the top 10 companies was 766 Mt, or about one-half of the national total. There was no change in the ranking of the five leading producing companies compared with the previous year.

A review of production by size of operation at the national level indicates that, in 2005, 959 Mt of crushed stone, or 56.9% of the total crushed stone total, was produced by 529 operations reporting more than 1 million metric tons per year; 423 Mt, or 25.1%, was produced by 639 operations reporting between 500,000 and 999,999 metric tons per year (t/yr); and 274 Mt, or 16.3%, was produced by 1,107 operations reporting between 100,000 and 499,999 t/yr. The production by size of operation information also indicates that 82.0% of total crushed stone produced in the United States in 2005 came from operations that produced more than 500,000 t/yr (table 7a). By geographic regions, in 2005, the South had 1,092 active operations, followed by the Midwest with 1,006 active operations and the West with 595 active operations (table 7b).

Merger and acquisition activity in the U.S. crushed stone industry in 2005 remained at relatively the same level as in 2004. Martin Marietta Materials, Inc. announced at the end of 2004 that it had formed a joint-venture company with Hunt Midwest Enterprises. The new company, Hunt Martin Materials, is equally owned by each party and will operate the aggregates operations owned by both companies in Kansas City and the surrounding area (Martin Marietta Materials, Inc., 2004).

Oglebay Norton had an active year in 2005, beginning with its emergence from Chapter 11 bankruptcy in January. In May, Oglebay Norton unified its limestone and lime operations by joining Michigan Limestone Operations and Global Stone under the new name of O-N Minerals (Rock Products, 2005b). In December, O-N Minerals sold their St. Clair underground mine in Oklahoma to United States Lime & Minerals, Inc. (Rock Products, 2006).

In March, the Switzerland-based Holcim Group acquired Aggregates Industries plc, which would increase the global cement manufacturer's market position in the U.S. cement, aggregates and ready-mix concrete markets. The transaction also allowed Holcim a place in the large, consolidated British market (Aggregates Manager, 2005).

In 2005, Vulcan bought 12 aggregates operations and 5 asphalt plants and sold the company's chemical business, Vulcan Chemicals. The five asphalt plants and five of the aggregates operations were acquired in March from New West Materials Co., L.L.C., an aggregates and asphalt producer in Phoenix and Tucson, AZ. In June, Vulcan Materials added the Long Branch Quarry in Georgia to the company's Southeast Division. In August, Vulcan Materials purchased multiple operations, including a crushed stone quarry in Tennessee, from Polk County Stone LLC., and four operations in northwest Indiana from the Critser family. In January 2006, Vulcan Materials expanded their Mideast Division with the purchase of the Penrose Quarry in North Carolina from Macon Construction, Inc. (Markley, 2006).

In November, CRH plc announced additions to its U.S. materials division, Oldcastle Materials. CRH acquired the aggregates, asphalt, paving and construction company Mountain Companies, which will be added into Oldcastle's Central Division. CRH also acquired Southern Minnesota Construction ("SMC") of Minnesota, an aggregates and asphalt supplier, to expand Oldcastle's West Division market (CRH plc, 2005). Also in November, Lafarge North America Inc. added three aggregates operations in Kansas by purchasing the aggregates, concrete, asphalt, and paving assets of Ritchie Corp. in Wichita, Kansas (Rock Products, 2005a).

Calcareous Marl.—Output of calcareous marl increased by 32.4% to 4.9 Mt valued at $28.3 million compared with 2004 (table 2). Marl was produced by five companies with six quarries in three States. The leading producers were, in descending order of tonnage, Holcim/Aggregate Industries; Lafarge North America; and Giant Group, Ltd.

Dolomite.—Production of dolomite increased by 4.5% to 95.2 Mt valued at $649 million compared with the total for 2004 (table 2). Crushed dolomite was reportedly produced by 85 companies at 186 operations with 205 quarries in 26 States. An additional undetermined amount of dolomite is included in the total crushed limestone, as explained in the limestone portion of the "Production" section.

The leading producing States were, in descending order of tonnage, Illinois, Pennsylvania, and New York; the total production of these three States was 42.1 Mt, or 44.2% of the total U.S. output (table 8). The leading producers were, in descending order of tonnage, Oldcastle, Material Services Corp., Hanson, Vulcan Materials, and Martin Marietta. Their combined total production was 47.2 Mt, or 49.6% of the U.S. dolomite total.

Granite.—The output of crushed granite increased by 1.2% to 263 Mt valued at $2.16 billion compared with 2004 (table 2). Crushed granite was produced by 129 companies at 364 operations with 339 quarries in 35 States. The leading States

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were, in descending order of tonnage, Georgia, North Carolina, Virginia, South Carolina, and California; the total production of these five States was 191 Mt, or 72.6% of the U.S. output (table 9). The leading producers were, in descending order of tonnage, Vulcan Materials, Martin Marietta, Hanson, Luck Stone Corp., and Florida Rock. Their combined total production was 165 Mt, or 63.1% of the U.S. granite total.

Limestone.—The 2005 output of crushed limestone, including some dolomite, increased by 3.3% to 1.1 Gt valued at $7.5 billion compared with 2004 (table 2). Limestone was produced by 686 companies at 1,800 operations with 1,867 quarries in 47 States. In addition, 37 companies with 61 operations and 61 quarries reported producing limestone and dolomite from the same quarries. Their production of about 33 Mt of limestone and dolomite combined is included with the limestone listed in table 2. The limestone totals listed in this chapter, therefore, include an undetermined amount of dolomite in addition to the dolomite reported separately.

The leading producing States were, in descending order of tonnage, Texas, Florida, Missouri, Ohio, and Tennessee; the total production of these five States was 461 Mt, or 42.5% of the total U.S. output (table 8). The leading producers of limestone were, in descending order of tonnage, Vulcan Materials, Martin Marietta, Hanson, Lafarge, and Rinker Materials. Their combined total production was 337 Mt, or 31.0% of the U.S. total.

Marble.—Production of crushed marble decreased by 21.7% to 7.8 Mt valued at $58.7 million compared with the total for 2004 (table 2). Crushed marble was produced by 12 companies with 22 operations and 20 quarries in 12 States. The leading producers of crushed marble were, in descending order of tonnage, Imerys Marble, Inc.; Omya, Inc.; Pluess Staufer Industries; Vulcan Materials; and Huber Engineered Materials. Their combined total production was 7.2 Mt, or 93.1% of the U.S. marble total.

Miscellaneous Stone.—Output of other kinds of crushed stone increased by 10.8% to 33.0 Mt valued at $226 million compared with 2004 (table 2). Miscellaneous stone was produced by 90 companies at 149 operations with 147 quarries in 29 States. The leading producing States were, in descending order of tonnage, Pennsylvania, North Carolina, California, Oregon, and Alaska; their combined production was 18.9 Mt, or 57.4% of the total U.S. output. Leading producers were, in descending order of tonnage, the U.S. Bureau of Land Management; Haines & Kibblehouse, Inc.; and Wake Stone Corp. Their combined total production was 10.1 Mt, or 30.6% of the U.S. miscellaneous stone total.

Sandstone and Quartzite.—The output of crushed sandstone and quartzite increased by 9.3% to 55.3 Mt valued at $387 million compared with the total for 2004 (table 2). Crushed sandstone was produced by 90 companies with 114 quarries in 22 States, while quartzite was produced by 33 companies with 40 quarries in 18 States.

The leading producing States were, in descending order of combined tonnage of sandstone and quartzite, Arkansas, Pennsylvania, Colorado, California, and South Dakota, and their combined total production was 32.3 Mt, or 58.4% of the U.S. output (table 9). The leading producers of sandstone and quartzite were, in descending order of tonnage, Lafarge; Martin Marietta; Ashland Paving and Construction, Inc. (APAC); CEMEX; and Pine Bluff Sand and Gravel Co. Their combined total production was 19.5 Mt, or 35.3% of the U.S. sandstone and quartzite total.

Shell.—Shell is derived mainly from fossil reefs or oyster shell banks. The output of crushed shell more than tripled to 4.42 Mt valued at $27.2 million compared with the 2004 total (table 2). Crushed shell was produced by nine companies with eight quarries in six States. The leading producers were, in descending order of tonnage, Schroeder-Manatee Ranch, Inc.; Caloosa Shell Corp.; and Langenfelder & Sons, Inc.

Slate.—The output of crushed slate decreased by 5.5% to 3.3 Mt and its value decreased by 11.7% to $23.6 million compared with 2004 (table 2). Crushed slate was produced by 15 companies at 16 quarries in 11 States. Most of the crushed slate was produced in North Carolina. The leading producers were, in descending order of tonnage, Martin Marietta, McCartney Construction, and NAPA Development Corp., Inc. Their combined total production was 2.3 Mt, or 69.8% of the U.S. slate total.

Traprock.—Production of crushed traprock increased by 5.0% to 130 Mt compared with 2004 total (table 2). Traprock was produced by 199 companies at 331 operations with 348 quarries in 24 States. The leading producing States were, in descending order of tonnage, Oregon, Virginia, New Jersey, California, and Washington; these five States produced 76.6 Mt, or 58.9% of U.S. output (table 9). Leading producers were, in descending order of tonnage, Oldcastle; Luck Stone; Vulcan Materials; MDU Resources Group, Inc.; and Deatley Co., Inc. Their combined total production was 52.7 Mt, or 40.5% of the U.S. traprock total.

Volcanic Cinder and Scoria.—Production of volcanic cinder and scoria increased by 54.8% to 3.0 Mt compared with the total for 2004 (table 2). Volcanic cinder and scoria were produced by 22 companies from 39 operations with 40 quarries in 13 States. Owing to the small numbers of companies operating in most States, only one or two, no State totals could be published for those States, and therefore leading producing States could not be identified (table 11). The leading producer was the U.S. Forest Service with about one-half of the 2005 production of volcanic cinder and scoria.

Consumption

Crushed stone production reported to the USGS is actually material that was either sold to other companies or consumers or was used by the producers. Stockpiled production is not included in the reported quantities. The "sold or used" tonnage, therefore, represents the amount of production released for domestic consumption or export in a given year. Because some of the crushed stone producers did not report a breakdown by end use, their total production is included in the "Unspecified, reported" use category. The estimated production of nonrespondents is included in the "Unspecified, estimated" use category.

In 2005, U.S. apparent consumption of crushed stone, which is defined as U.S. production plus imports minus exports, was 1.71 Gt, a 3.7% increase compared with the apparent consumption

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of 2004. Of the 1.71 Gt of crushed stone consumed, 540 Mt, or 31.7% of the total, was "Unspecified, reported," and 304 Mt, or 17.8% of the total, was "Unspecified, estimated." Of the remaining 841 Mt, reported by uses by producers, 84.7% was used as construction aggregate, mostly for highway and road construction and maintenance as well as residential construction and sewers; 12.4%, for chemical and metallurgical uses, including cement and lime manufacture; 1.6%, for agricultural uses; and 1.4%, for special and miscellaneous uses and products (table 13). Unspecified uses are not included in the calculation of the above percentages. It is suggested that, in marketing analysis or use-pattern studies, the quantities included in unspecified uses be prorated and added to the reported uses by applying the above percentages calculated for the reported quantities. Using this procedure, the analyst assumes that the breakdown by uses of the unspecified uses is similar to that of the reported uses.

In 2005, the value of the total construction put in place increased to $1,140 billion, or 10.5%, as reported by the U.S. Census Bureau (2006§[1]). The value of total private construction increased by 11.8% to $899 billion, while the value of total public construction increased by 6.2% to $245 billion. The value of private construction showed signs of slower growth when compared with the 14.4% increase reported in 2004. The public construction sector recorded its largest increase since 2001, and the 6.2% increase in 2005 was an improvement compared with last year's 2.9% increase.

In 2005, there was also a 5.4% increase in the U.S. consumption of portland cement to 124 Mt compared with the 2004 total consumption of 117 Mt, another indication of increased construction activity at the national level.

Calcareous Marl.—Of the 4.9 Mt of crushed calcareous marl consumed, 2.5 Mt, or 50.1% of the total, was in "Unspecified, uses." Most of the remaining 2.5 Mt was used for cement manufacturing.

Dolomite.—Of the 95.2 Mt of crushed dolomite consumed, 29.0 Mt or 30.5% of the total, was in "Unspecified, reported" uses, and 8.4 Mt, or 8.9% of the total, was in "Unspecified, estimated" uses. Of the remaining 57.8 Mt of crushed dolomite reported by uses by the producers, 51.0 Mt, or 88.2%, was used as construction aggregates; 3.5 Mt, or 6%, was used for chemical and metallurgical applications, and 1.2 Mt, or 2%, for agricultural uses. An additional undefined amount of dolomite consumed in a variety of uses, mostly construction aggregates, is reported with limestone (table 14).

Additional detailed information for total combined limestone and dolomite by State and major uses is provided in table 15.

Granite.—Of the 263 Mt of crushed granite consumed, 119 Mt, or 45.3%, was in "Unspecified, reported" uses, and 31 Mt, or 11.8%, was in "Unspecified, estimated" uses. Most of the remaining 113 Mt was used as construction aggregates (table 17).

Limestone.—Of the 1,090 Mt of crushed limestone consumed, 294 Mt, or 27.1% of the total, was in "Unspecified, reported" uses, and 214 Mt, or 19.8% of the total, was in "Unspecified, estimated" uses. Of the remaining 577 Mt of crushed limestone, reported by uses by the producers, 464 Mt, or 80.4%, was used as construction aggregate; 94.2 Mt, or 16.3%, was used for chemical and metallurgical applications, including cement and lime manufacturing; 11.5 Mt, or 2.0%, for agricultural uses; and 4.2 Mt, or 0.7%, for special and miscellaneous uses and products (table 14).

Marble.—Of the 7.8 Mt of crushed marble consumed 4 Mt, or 51.7%, was in "Unspecified, estimated." Of the remaining 3.8 Mt of crushed marble reported by uses by the producers, 2.9 Mt, or 77.3%, was used as construction aggregates; 608,000 metric tons (t), or 16.2%, was used for special uses including fillers and extenders, and 241,000 t, or 6.4%, for agricultural uses (table 16).

Miscellaneous Stone.—Of the 33.0 Mt of miscellaneous crushed stone consumed, 12.3 Mt, or 37.1% of the total, was in "Unspecified, reported" uses, and 8.2 Mt, or 24.9% of the total, was in "Unspecified, estimated" uses. Construction aggregate accounted for more than 90% of the remaining 12.5 Mt reported by uses by the producers (table 19).

Sandstone and Quartzite.—Of the 37.2 Mt of crushed sandstone consumed, 14.0 Mt, or 37.8%, was in "Unspecified, reported" uses, and 10.9 Mt or 29.3%, in "Unspecified, estimated." Most of the remaining 12.2 Mt of crushed sandstone reported by uses by the producers was used as construction aggregates (table 18).

Of the 18.1 Mt of crushed quartzite consumed in the United States, 9.5 Mt, or 52.2% of the total, was in "Unspecified, reported" uses, and 2.3 Mt, or 12.8% of the total, was in "Unspecified, estimated" uses. Most of the remaining 6.4 Mt of crushed quartzite reported by uses by the producers was used as construction aggregate (table 18).

Shell.—Of the 4.4 Mt of crushed shell consumed, 480,000 t, or 10.9%, was reported as "Unspecified, uses." Most of the remaining 3.9 Mt was used as construction aggregate.

Slate.—Of the 3.3 Mt of crushed slate consumed, two-thirds of the total, or 2.2 Mt, was in "Unspecified, uses." The remaining one-third was used as construction aggregate including roofing granules.

Traprock.—Of the 130 Mt of crushed traprock consumed, 58.8 Mt, or 45.2%, was in "Unspecified, reported" uses, and 21.5 Mt, or 16.5%, was in "Unspecified, estimated" uses. Most of the remaining 49.9 Mt was used as construction aggregate (table 17).

Volcanic Cinder and Scoria.—Of the 3.0 Mt of volcanic cinder and scoria consumed, 1.6 Mt, or 53.5% of the total, was in "Unspecified, reported" uses, and 286,000 t, or 9.7% of the total, was in "Unspecified, estimated" uses. Most of the remaining 1.1 Mt of crushed volcanic cinder and scoria was used as construction aggregate (table 19).

Additional information regarding production and consumption of crushed stone by type of rock and major uses in each State and the State districts may be found in the USGS Minerals Yearbook, volume II, Area Reports: Domestic.

Recycling

As the recycling of most waste materials increases, aggregates producers are recycling more cement concrete and asphalt concrete materials recovered from construction projects to produce concrete and asphalt aggregates and other aggregate materials, especially fill and road base. The recycling of cement

[1]A reference that includes a section mark (§) is found in the Internet Reference Cited section.

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concrete is done at some quarries and increasingly at sales yards or distribution sites, whereas asphalt concrete is recycled mostly at the construction sites. The annual survey of crushed stone producers collects information on recycling of cement and asphalt concretes produced by the crushed stone producers only. These amounts represent a small percentage of the total recycled cement and asphalt concretes because the recycling of these materials is done mostly by construction or demolition companies, and those companies are not surveyed by the USGS.

Asphalt Concrete.—A total of 1.9 Mt of asphalt concrete valued at $17.7 million was recycled in 2005 by 46 companies in 21 States. The tonnage of recycled asphalt concrete decreased by 17.1% compared with the 2004 total (tables 20, 21). The leading recycling geographic regions were, in descending order of tonnage, the Northeast with 591,000 t, the West with 549,000 t, and the South, with 499,000 t (table 20). The leading recycling States were, in descending order of tonnage, California, Florida, Pennsylvania, New York, and Indiana. Their combined total represented 67.8% of the U.S. total. The leading recycling companies, in descending order of tonnage produced, were Vecellio & Grogan, Inc.; Oldcastle; and Hanson.

Cement Concrete.—A total of 3.9 Mt of portland cement concrete valued at $29.4 million was recycled by 40 companies in 19 States. This tonnage represents a 37.2% increase compared with 2004 (tables 22, 23). The leading recycling geographic regions were, in descending order of tonnage, the Midwest with 1.7 Mt, the West with 1.6 Mt, and the South with 332,000 t. The leading recycling States were, in descending order of tonnage, Illinois, California, Virginia, New York, and Wisconsin. Their combined total represented 95.5% of the U.S. total. The leading companies were, in descending order of tonnage produced, Vulcan Materials, Stevens Creek Quarry Inc., and Oldcastle.

Prices

Prices in this chapter are the average annual free on board plant prices, usually at the first point of sale or captive use, as reported by the crushed stone producing companies. This value does not include transportation from the plant or yard to the consumer. It does, however, include all costs of mining, processing, in-plant transportation, overhead costs, and profit. In 2005, fewer than one-half of the operations responding to the annual survey reported the value of their production. The number of operations that reported the value of their production increased slightly in 2005. The average unit value for operations reporting production and value in 2005 was $7.26. This was an increase of 8.2% compared with the average unit value of $6.71 in 2004. The annual reports of the top three U.S. producing companies reported an 8% price increase in 2005 compared with prices in 2004. The average unit prices, by kind of stone, increased for every stone type except slate (table 2). For those operations that reported production only, the unit values of total production or specific end uses were estimated based on what other operations in the same State reported. The average unit value for specific end uses within a State was used in the estimation of value for operations reporting specific end uses. The State average was used in the estimation for operations reporting a total production but not total value. The estimation process was modified from previous years to align with the methodology used in the construction sand and gravel chapter.

Additional information regarding prices of crushed stone by type of rock and uses in the United States and each State and the State districts may be found throughout the tables included in this chapter as well as in the USGS Minerals Yearbook, volume II, Area Reports: Domestic.

Transportation

For 883 Mt, or 52.4%, of the 1.69 Gt of crushed stone produced for consumption in 2005, no means of transportation was reported by the producers. Of the remaining 802 Mt of crushed stone, 669 Mt, or 83.4%, was reported as being transported by truck from the quarry or the processing plant to the first point of sale or use; 48.7 Mt, or 6.1%, by rail; and 23.8 Mt, or 3.0%, by waterway. For 48.9 Mt, or 6.1%, of the specified production was reported as not having been transported and, therefore, is assumed to have been used onsite (table 24).

Shipment by truck remains the most widely used method of transportation for crushed stone. The significant increase in the number of sales and distribution yards in the past couple of years and the increase in the volume of crushed stone going through these sites have had a positive impact on the industry as well as the communities they serve. Distribution sites located near metropolitan areas significantly reduce the distance most trucks have to travel to pick up and deliver crushed stone. Therefore the transportation costs are reduced, as is the impact of heavy traffic on the infrastructure and the environment. Sales yards serve both to distribute products and increasingly as recycling sites. This provides efficiency for the industry while helping protect the environment.

Information regarding means of transportation used by the producers to ship crushed stone from the production site to the consumer in each geographic region is provided in table 24.

Foreign Trade

The widespread distribution of domestic deposits of stone suitable for mining as crushed stone, the large number of existing active operations around the country, and the high cost of transportation limit foreign trade to mostly local transactions across international boundaries. Shipments of crushed stone by water, especially from Canada, the Caribbean, and Mexico, continue to increase. U.S. imports and exports continue to be small, representing little more than 1% of domestic consumption.

Exports.—Exports of crushed stone decreased in 2005 by 1.2% to 1.26 Mt compared with the total of 1.28 Mt of 2004, and the value decreased by 7.4% to $50.5 million. In 2005, one-half of the exported crushed stone was limestone for cement manufacturing valued at an average unit price of $20.73 per metric ton, and 11.1% of the exported crushed stone was limestone used as construction aggregate valued at an average unit value of $24.98 per ton (table 26).

Imports.—Imports of crushed stone increased by 12.6% to 21 Mt compared with those of 2004, and the value increased by 8.7% to $194 million. Of the imported crushed stone, 57.1%

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was limestone used as construction aggregate, as flux stone, and in cement manufacturing. Imports of natural calcium carbonate fines almost doubled in value to $517,000 in 2005 from $286,000 in 2004 (table 27).

The total amount of imported crushed stone is a very small tonnage compared with the total U.S. production. While imports of crushed stone are expected to increase in the future, they will continue to be a very small percentage of total U.S. consumption.

Outlook

Consumption of crushed stone in 2006 is expected to continue at the current level or decrease slightly compared with 2005. Construction spending should continue to benefit from economic growth and improving fiscal conditions at the State and local levels. Increases in infrastructure and commercial construction could be somewhat offset by an overall decline in residential construction. In some markets, especially in the South, the recovery in private nonresidential construction should continue in 2006 and residential construction activity should remain flat. Crushed stone prices are expected to increase owing to the heavy demand, higher input costs—including rising transportation costs—and increasing scarcity of well-located mineral reserves in many of the U.S. market areas.

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TABLE 1
SALIENT CRUSHED STONE STATISTICS[1]

(Thousand metric tons and thousand dollars)

	2001	2002	2003	2004	2005
Sold or used by producers:[2]					
Quantity	1,590,000	1,510,000	1,530,000	1,630,000 r	1,690,000
Value	8,870,000	8,650,000	9,060,000	9,890,000 r	12,100,000
Exports, value	35,600	54,000	45,600	54,500	50,500
Imports, value[3]	110,000	124,000	143,000	179,000	194,000

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[1]Data are rounded to no more than three significant digits.

[2]Does not include American Samoa, Guam, Puerto Rico, and the U.S. Virgin Islands.

[3]Excludes precipitated calcium carbonate.

TABLE 2
CRUSHED STONE SOLD OR USED IN THE UNITED STATES, BY KIND[1, 2]

	2004				2005			
Kind	Number of quarries	Quantity (thousand metric tons)	Value (thousands)	Unit value	Number of quarries	Quantity (thousand metric tons)	Value (thousands)	Unit value
Limestone[3]	1,873 r	1,050,000 r	$5,970,000 r	$5.68 r	1,904	1,090,000	$7,490,000	$6.90
Dolomite	209 r	91,100 r	535,000 r	5.87 r	205	95,200	649,000	6.82
Marble	25 r	9,910 r	69,500 r	7.01 r	21	7,760	58,700	7.57
Calcareous marl	7	3,740	16,100	4.30	6	4,950	28,300	5.73
Shell	7	1,450	8,240	5.67	8	4,420	27,200	6.15
Granite	342 r	260,000 r	1,870,000 r	7.19 r	339	263,000	2,160,000	8.21
Traprock	370 r	124,000 r	878,000 r	7.08 r	348	130,000	1,040,000	7.97
Sandstone and quartzite[4]	162	50,600 r	325,000 r	6.43 r	154	55,300	387,000	7.00
Slate	16	3,530	26,800	7.58	16	3,340	23,600	7.08
Volcanic cinder and scoria	39 r	1,910 r	13,200 r	6.90 r	40	2,960	21,400	7.21
Miscellaneous stone	144 r	29,800 r	181,000	6.09 r	147	33,000	226,000	6.85
Total or average	XX	1,630,000 r	9,890,000 r	6.08 r	XX	1,690,000	12,100,000	7.18

rRevised. XX Not applicable.

[1]Data are rounded to no more than three significant digits, except unit values and number of quarries; may not add to totals shown.

[2]Does not include American Samoa, Guam, Puerto Rico, and the U.S. Virgin Islands.

[3]Includes limestone-dolomite reported with no distinction between the two kinds of stone.

[4]Includes sandstone-quartzite reported with no distinction between the two kinds of stone.

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TABLE 3

CRUSHED STONE SOLD OR USED IN THE UNITED STATES, BY GEOGRAPHIC DIVISION[1, 2]

(Thousand metric tons and thousand dollars)

Region/division	2004		2005	
	Quantity	Value[r]	Quantity	Value
Northeast:				
New England	39,600 [r]	282,000	40,000	336,000
Middle Atlantic	188,000 [r]	1,150,000	181,000	1,310,000
Midwest:				
East North Central	285,000 [r]	1,440,000	284,000	1,660,000
West North Central	173,000 [r]	1,050,000	180,000	1,310,000
South:				
South Atlantic	412,000 [r]	2,820,000	438,000	3,660,000
East South Central	172,000 [r]	1,100,000	176,000	1,280,000
West South Central	200,000 [r]	1,050,000	223,000	1,370,000
West:				
Mountain	60,500 [r]	355,000	61,200	375,000
Pacific	97,900	641,000	103,000	805,000
Total or average	1,630,000 [r]	9,890,000	1,690,000	12,100,000

[r]Revised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Does not include American Samoa, Puerto Rico, and the U.S. Virgin Islands.

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TABLE 4

CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1, 2]

State	2004 Quantity (thousand metric tons)	2004 Value (thousands)	2004 Unit value	2005 Quantity (thousand metric tons)	2005 Value (thousands)	2005 Unit value
Alabama	47,800 r	$296,000 r	$6.19 r	49,500	$325,000	$6.57
Alaska[3]	2,270 r	14,200 r	6.25 r	2,360	15,600	6.60
Arizona[4]	14,100 r	75,900 r	5.37 r	12,000	69,300	5.75
Arkansas[5]	34,100 r	173,000 r	5.07 r	35,400	223,000	6.29
California[6]	55,300 r	364,000 r	6.59 r	54,300	455,000	8.37
Colorado	11,100 r	68,300 r	6.14 r	13,000	89,100	6.85
Connecticut	10,100 r	75,700	7.53	10,100	92,600	9.19
Delaware[7]	--	--	--	W	W	6.89
Florida[8]	105,000	680,000 r	6.50 r	115,000	994,000	8.67
Georgia	79,700 r	548,000 r	6.88 r	79,400	606,000	7.63
Hawaii	5,470 r	61,300 r	11.21 r	6,170	82,300	13.34
Idaho	3,420 r	18,100 r	5.30 r	4,450	23,900	5.37
Illinois	75,300 r	462,000 r	6.14 r	76,200	545,000	7.16
Indiana	56,800	265,000 r	4.68 r	57,500	311,000	5.40
Iowa	35,800 r	219,000 r	6.12 r	34,500	251,000	7.27
Kansas	20,600 r	122,000 r	5.93 r	22,100	159,000	7.20
Kentucky[9]	62,100 r	384,000 r	6.18 r	58,200	421,000	7.24
Louisiana[10]	W	W	11.27 r	W	W	8.18
Maine	4,370	29,500	6.75	4,490	30,700	6.85
Maryland	35,300 r	214,000 r	6.05 r	33,100	274,000	8.28
Massachusetts	13,700 r	109,000	7.97 r	13,200	121,000	9.19
Michigan[11]	36,700 r	143,000 r	3.90 r	36,100	141,000	3.89
Minnesota[12]	10,400 r	64,900 r	6.24 r	10,500	86,900	8.30
Mississippi[13]	2,760	34,200	12.40	3,500	41,700	11.90
Missouri	92,600 r	564,000 r	6.09 r	99,400	733,000	7.37
Montana	4,090	13,700 r	3.35 r	3,540	16,800	4.76
Nebraska	6,900	51,900	7.52	6,950	49,300	7.10
Nevada	9,760	72,800	7.46	9,320	66,800	7.17
New Hampshire	4,720 r	23,900 r	5.06	5,100	40,900	8.02
New Jersey[14]	25,400 r	185,000 r	7.29 r	22,700	160,000	7.04
New Mexico[15]	2,830 r	16,400 r	5.79 r	3,010	20,100	6.67
New York	49,400 r	327,000 r	6.62	52,700	445,000	8.44
North Carolina	72,300 r	549,000 r	7.59	74,300	638,000	8.59
North Dakota[16]	W	W	3.88 r	89	396	4.45
Ohio	76,500 r	396,000 r	5.17 r	75,200	437,000	5.82
Oklahoma	39,800	206,000 r	5.19 r	45,400	257,000	5.67
Oregon	22,700 r	126,000	5.54 r	26,000	157,000	6.01
Pennsylvania	113,000 r	639,000 r	5.68 r	106,000	704,000	6.67
Rhode Island[17]	1,600	12,400	7.74	1,610	12,400	7.74
South Carolina[18]	31,300	210,000	6.70	33,800	258,000	7.61
South Dakota	6,410 r	27,600 r	4.30 r	6,650	30,600	4.60
Tennessee	57,900	381,000 r	6.58 r	63,900	482,000	7.55
Texas	122,000	621,000 r	5.11 r	134,000	823,000	6.15
Utah	8,030 r	45,100 r	5.62 r	8,350	46,600	5.58
Vermont[19]	5,110	30,800	6.03	5,480	37,000	6.75
Virginia[20]	73,700 r	540,000 r	7.33 r	86,200	778,000	9.03
Washington	12,100 r	75,500 r	6.25 r	13,900	96,300	6.92
West Virginia	14,700	72,600 r	4.95 r	14,500	99,400	6.86
Wisconsin	39,300 r	172,000 r	4.38 r	38,900	227,000	5.83
Wyoming	6,300 r	35,300 r	5.60 r	7,370	41,800	5.68
Other	7,240 r	71,400 r	9.86 r	11,000	86,500	7.89
Total or average	1,630,000 r	9,890,000 r	6.08 r	1,690,000	12,100,000	7.18

See footnotes at end of table.

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TABLE 4—Continued

CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1, 2]

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[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]To avoid disclosing company proprietary data, certain State totals do not include all kinds of stone produced within the State; the portion not shown has been included with "Other."

[3]Data derived, in part, from Alaska Division of Geological and Geophysical Surveys information.

[4]Excludes traprock (2005).

[5]Excludes slate.

[6]Excludes shell (2004).

[7]Excludes limestone.

[8]Excludes sandstone.

[9]Excludes dolomite.

[10]A significant amount of sold or used material was shipped in from other States. Excludes limestone and sandstone.

[11]Excludes calcareous marl (2004).

[12]Excludes quartzite (2004).

[13]A significant amount of sold or used material was shipped in from other States.

[14]Excludes miscellaneous stone (2004).

[15]Excludes granite (2004).

[16]Excludes granite, traprock, volcanic cinder, and miscellaneous stone (2004).

[17]Excludes limestone.

[18]Excludes marble (2005).

[19]Excludes slate (2005).

[20]Excludes marble (2004).

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TABLE 5

CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY QUARTER AND GEOGRAPHIC DIVISION[1, 2]

Region/division	Quantity, 1st quarter (thousand metric tons)	Percentage change[3]	Quantity, 2d quarter (thousand metric tons)	Percentage change[3]	Quantity, 3d quarter (thousand metric tons)	Percentage change[3]	Quantity, 4th quarter (thousand metric tons)	Percentage change[3]	Total[4] Quantity (thousand metric tons)	Total[4] Value (thousands)
Northeast:										
New England	2,610	-10.9	12,000	7.3	13,400	-4.0	10,300	-9.8	38,300	$283,000
Middle Atlantic	22,500	-3.2	58,100	7.3	60,500	-7.4	44,700	-6.0	186,000	1,190,000
Midwest:										
East North Central	34,700	-2.3	78,700	--	84,100	-8.8	72,200	-7.0	270,000	1,400,000
West North Central	27,700	15.9	48,000	13.8	51,200	11.3	38,500	4.8	165,000	1,030,000
South:										
South Atlantic	88,600	4.5	112,000	2.7	115,000	6.2	102,000	-1.1	418,000	2,990,000
East South Central	33,900	3.9	46,400	7.8	45,600	-5.4	45,700	9.8	172,000	1,150,000
West South Central	50,100	16.5	58,000	17.3	57,500	4.4	52,200	10.4	218,000	1,090,000
West:										
Mountain	10,800	3.5	15,600	-1.9	18,800	1.3	13,700	6.0	58,900	352,000
Pacific[5]	18,000	1.5	23,200	-1.7	25,400	-4.1	23,900	5.7	90,500	587,000
Total or average[4]	297,000	5.5	453,000	5.7	470,000	-0.2	405,000	0.5	1,630,000 [6]	10,100,000

-- Zero.

[1]As published in the "Crushed Stone and Sand and Gravel in the Fourth Quarter of 2005" Mineral Industry Surveys.

[2]Quarterly totals shown are estimates based on a sample survey. Estimated quantities for prior quarters have been recalculated.

[3]All percentage changes are calculated by using unrounded totals. Percentage changes are based on the corresponding quarter of the previous year.

[4]Data may not add to totals shown because of independent rounding and differences between projected totals by States and region.

[5]Does not include Alaska and Hawaii.

[6]Includes Alaska, Hawaii, and other States as detailed in table 6.

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TABLE 6

CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY QUARTER AND STATE[1, 2]

State	Quantity, 1st quarter (thousand metric tons)	Percentage change[3]	Quantity, 2d quarter (thousand metric tons)	Percentage change[3]	Quantity, 3d quarter (thousand metric tons)	Percentage change[3]	Quantity, 4th quarter (thousand metric tons)	Percentage change[3]	Total[4] Quantity (thousand metric tons)	Total[4] Value (thousands)
Alabama	10,800	-2.8	12,900	2.7	12,800	-2.3	11,400	-7.4	47,900	$308,000
Alaska	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)
Arizona	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	14,700	79,100
Arkansas	8,120	19.5	9,420	9.5	9,770	1.9	8,710	9.7	36,000	183,000
California	10,600	-9.6	14,100	-1.1	15,100	-1.6	13,600	-3.6	53,300	366,000
Colorado	2,100	45.2	3,210	3.9	3,940	1.6	2,560	-1.1	11,800	75,200
Connecticut	579	-18.5	3,110	9.9	3,390	-4.3	2,660	-10.4	9,740	76,300
Delaware	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)
Florida	28,000	9.5	26,700	-1.6	28,100	11.4	29,100	6.4	112,000	747,000
Georgia	17,300	-5.8	20,900	-0.7	21,900	3.7	19,600	3.6	79,700 [6]	568,000
Hawaii	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)
Idaho	710	-16.9	1,110	76.6	1,070	34.2	842	-18.7	3,740	20,400
Illinois	10,500	13.0	23,700	19.1	25,200	2.1	22,700	0.5	82,100 [6]	519,000
Indiana	8,150	1.8	16,600	4.3	17,100	-8.8	14,500	2.5	56,300	261,000
Iowa	5,000	16.6	11,800	8.4	13,100	12.6	9,750	-2.1	39,700	241,000
Kansas	4,550	10.6	6,680	25.2	6,490	16.4	5,430	13.9	23,200	132,000
Kentucky	8,630	-11.0	13,800	-5.3	14,100	-19.4	17,900	29.4	54,500	354,000
Louisiana	(6, 7)	(6, 7)	(6, 7)	(6, 7)	(6, 7)	(6, 7)	(6, 7)	(6, 7)	(6, 7)	(6, 7)
Maine	483	16.9	1,240	-6.3	1,400	-12.3	902	-13.2	4,020	28,200
Maryland	5,330	8.2	8,530	0.1	8,550	-0.8	7,410	-5.1	29,800 [6]	192,000
Massachusetts	764	-27.1	4,140	5.2	4,070	-9.1	3,470	-17.0	12,400	103,000
Michigan	3,290	-1.2	8,640	-19.1	9,850	-17.3	9,060	-8.3	30,800 [6]	125,000
Minnesota	498	-0.8	3,460	-7.4	4,840	10.0	2,230	-1.5	11,000	71,900
Mississippi	(6, 7)	(6, 7)	(6, 7)	(6, 7)	(6, 7)	(6, 7)	(6, 7)	(6, 7)	3,660	47,200
Missouri	15,800	19.4	22,400	22.2	23,000	10.0	18,100	9.0	79,300	496,000
Montana	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	4,170	18,500
Nebraska	1,050	0.4	2,020	1.5	2,090	4.2	1,830	-1.7	6,990	54,700
Nevada	2,100	-10.9	2,420	-22.3	2,260	-2.2	2,060	4.5	8,850	68,600
New Hampshire	320	8.5	1,500	8.3	1,850	8.0	1,460	7.6	5,120	27,000
New Jersey	3,370	24.9	8,390	32.9	8,000	-8.7	6,920	-10.3	26,700	202,000
New Mexico	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	651	4,810
New York	4,710	2.4	17,200	5.2	19,400	-5.1	12,900	14.6	54,300	374,000
North Carolina	14,500	7.0	20,400	1.8	21,000	5.7	16,800	-10.9	72,600	573,000
North Dakota	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)	(5, 6)
Ohio	8,790	-16.1	20,400	-4.1	21,300	-11.0	17,300	-16.6	67,800	355,000
Oklahoma	10,600	11.3	11,900	15.5	11,300	2.8	9,860	4.5	43,600	219,000
Oregon	4,650	20.1	6,430	3.5	7,440	0.5	6,750	27.2	25,300	14,500
Pennsylvania	14,600	-10.4	32,200	2.6	32,700	-8.5	24,700	-13.8	104,000	614,000
Rhode Island	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	1,730	13,900
South Carolina	7,570	10.9	8,910	8.4	9,540	13.2	8,310	5.7	34,300	239,000
South Dakota	810	34.4	1,780	-2.3	2,010	15.3	1,150	-4.7	5,750	30,100
Tennessee	13,100	19.3	18,400	19.7	17,300	2.3	16,200	10.3	65,000	445,000
Texas	31,500	18.9	36,900	20.2	36,600	5.5	33,600	12.8	139,000	691,000
Utah	1,660	13.8	2,160	-3.9	2,790	-1.5	2,190	47.0	8,800	51,100
Vermont	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	5,500	34,500
Virginia	14,600	5.0	22,100	11.9	21,300	5.9	17,700	-5.4	75,700	593,000
Washington	2,800	34.6	2,590	-17.0	2,830	-26.1	3,660	12.7	11,900	76,500
West Virginia	2,580	9.2	4,320	4.2	4,300	-1.4	3,360	-12.0	14,600	75,400
Wisconsin	3,650	-1.7	8,600	-17.4	11,100	-22.3	7,960	-22.2	31,300	141,000
Wyoming	861	-20.4	1,770	-9.5	2,770	13.8	1,470	-12.2	6,880	34,500
Other	XX	XX	XX	XX	XX	XX	XX	XX	13,800	109,000
Total	XX	XX	XX	XX	XX	XX	XX	XX	1,630,000	10,100,000

See footnotes at end of table.

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TABLE 6—Continued

CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY QUARTER AND STATE[1, 2]

XX Not applicable.

[1]As published in the "Crushed Stone and Sand and Gravel in the Fourth Quarter of 2005" Mineral Industry Surveys.

[2]Quarterly totals shown are estimates based on a sample survey. Estimated quantities for prior quarters have been recalculated.

[3]All percentage changes are calculated by using unrounded totals. Percentage changes are based on the corresponding quarter of the previous year.

[4]Data may not add to totals shown because of independent rounding and differences between projected totals by States and regions.

[5]State not included in quarterly survey.

[6]To avoid disclosing proprietary data, data for certain States do not include all types of stone produced within the State; the portion not shown has been included with "Other."

[7]Owing to the low number of companies, no production estimates by quarter were generated.

TABLE 7A

CRUSHED STONE SOLD OR USED IN THE UNITED STATES IN 2005, BY SIZE OF OPERATION[1]

	U.S. total			
Size range (metric tons)	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	358	11.5	2,860	(2)
25,000 to 49,999	192	6.2	6,470	(2)
50,000 to 99,999	289	9.3	19,400	0.1
100,000 to 199,999	362	11.6	48,100	0.3
200,000 to 299,999	307	9.9	69,700	0.4
300,000 to 399,999	256	8.2	82,900	0.5
400,000 to 499,999	182	5.8	73,600	0.4
500,000 to 599,999	137	4.4	67,900	0.4
600,000 to 699,999	145	4.7	85,700	0.5
700,000 to 799,999	165	5.3	113,000	0.7
800,000 to 899,999	86	2.8	66,500	0.4
900,000 to 999,999	106	3.4	90,000	0.5
1,000,000 to 1,499,999	256	8.2	283,000	17.0
1,500,000 to 1,999,999	126	4.0	195,000	12.0
2,000,000 to 2,499,999	61	2.0	125,000	0.7
2,500,000 to 4,999,999	69	2.2	218,000	13.0
5,000,000 and more	17	0.5	138,000	0.8
Total	3,114	100.0	1,690,000	100.0

[1]Data are rounded to no more than three significant digits except "Number of operations;" may not add to totals shown.

[2]Less than ½ unit.

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TABLE 7B

CRUSHED STONE SOLD OR USED IN THE UNITED STATES IN 2005, BY REGION AND SIZE OF OPERATION[1]

Size range (metric tons)	Northeast				Midwest			
	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	29	6.9	201	(2)	114	11.3	1,110	(2)
25,000 to 49,999	13	3.1	432	(2)	81	8.1	2,760	0.1
50,000 to 99,999	24	5.7	1,740	0.1	109	10.8	7,140	0.2
100,000 to 199,999	59	14.0	8,010	0.4	145	14.4	18,800	0.4
200,000 to 299,999	42	10.0	9,880	0.4	106	10.5	23,800	0.5
300,000 to 399,999	45	10.7	14,400	0.7	97	9.6	32,000	0.7
400,000 to 499,999	40	9.5	16,200	0.7	56	5.6	22,600	0.5
500,000 to 599,999	31	7.4	15,500	0.7	39	3.9	19,200	0.4
600,000 to 699,999	23	5.5	13,600	0.6	45	4.5	26,600	0.6
700,000 to 799,999	14	3.3	9,600	0.4	30	3.0	20,300	0.4
800,000 to 899,999	22	5.2	17,000	0.8	20	2.0	15,500	0.3
900,000 to 999,999	7	1.7	6,160	0.3	35	3.5	29,900	0.6
1,000,000 to 1,499,999	40	9.5	43,600	20.0	66	6.6	73,800	16.0
1,500,000 to 1,999,999	17	4.0	26,700	12.0	25	2.5	38,600	0.8
2,000,000 to 2,499,999	8	1.9	16,700	0.8	16	1.6	32,900	0.7
2,500,000 to 4,999,999	7	1.7	21,300	10.0	17	1.7	53,400	12.0
5,000,000 and more	--	--	--	--	5	0.5	45,800	10.0
Total	421	100.0	221,000	100.00	1,006	100.0	464,000	100.00

	South				West			
	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total	Number of operations	Percentage of total	Quantity (thousand metric tons)	Percentage of total
Less than 25,000	47	4.3	385	(2)	168	28.2	1,170	(2)
25,000 to 49,999	41	3.8	1,340	(2)	57	9.6	1,940	0.1
50,000 to 99,999	69	6.3	4,470	0.1	87	14.6	6,020	0.4
100,000 to 199,999	86	7.9	11,700	0.1	72	12.1	9,590	0.6
200,000 to 299,999	111	10.2	25,000	0.3	48	8.1	11,000	0.7
300,000 to 399,999	81	7.4	25,600	0.3	33	5.5	11,000	0.7
400,000 to 499,999	58	5.3	23,600	0.3	28	4.7	11,200	0.7
500,000 to 599,999	56	5.1	27,700	0.3	11	1.8	5,510	0.3
600,000 to 699,999	60	5.5	35,500	0.4	17	2.9	10,000	0.6
700,000 to 799,999	107	9.8	73,800	0.9	14	2.4	9,700	0.6
800,000 to 899,999	36	3.3	27,800	0.3	8	1.3	6,240	0.4
900,000 to 999,999	61	5.6	51,300	0.6	3	0.5	2,620	0.2
1,000,000 to 1,499,999	124	11.4	137,000	16.0	26	4.4	28,400	17.0
1,500,000 to 1,999,999	74	6.8	114,000	14.0	10	1.7	15,700	10.0
2,000,000 to 2,499,999	29	2.7	59,100	0.7	8	1.3	16,400	10.0
2,500,000 to 4,999,999	41	3.8	131,000	16.0	4	0.7	11,900	0.7
5,000,000 and more	11	1.0	86,700	10.0	1	0.2	5,620	0.3
Total	1,092	100.0	837,000	100.0	595	100.0	164,000	100.0

-- Zero.

[1]Data are rounded to no more than three significant digits except "number of operations;" may not add to totals shown.

[2]Less than ½ unit.

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TABLE 8
CRUSHED LIMESTONE AND DOLOMITE SOLD OR USED BY PRODUCERS
IN THE UNITED STATES IN 2005, BY STATE[1]

(Thousand metric tons and thousand dollars)

State	Limestone		Dolomite	
	Quantity	Value	Quantity	Value
Alabama	41,000	269,000	W	W
Arizona	6,340 [2]	33,200 [2]	--	--
Arkansas	13,500	81,700	W	W
California	21,700 [2]	161,000 [2]	W	W
Colorado	1,540	11,300	W	W
Connecticut	W [2]	W [2]	W	W
Delaware	W	W	--	--
Florida	110,000 [2]	963,000 [2]	982	7,370
Georgia	8,690	66,900	--	--
Hawaii	W	W	--	--
Idaho	W	W	--	--
Illinois	56,600 [2]	400,000 [2]	19,500	144,000
Indiana	47,700 [2]	250,000 [2]	9,750	60,200
Iowa	32,600 [2]	237,000 [2]	W	W
Kansas	21,500	155,000	--	--
Kentucky	58,200 [2]	421,000 [2]	W	W
Louisiana[3]	W	W	--	--
Maine	1,940	12,500	--	--
Maryland	21,400 [2]	181,000 [2]	--	--
Massachusetts	W [2]	W [2]	W	W
Michigan	27,900	108,000	7,380	31,200
Minnesota	W [2]	W [2]	W	W
Mississippi[3]	3,500	41,700	--	--
Missouri	93,300 [2]	631,000 [2]	3,860	26,400
Montana	2,550	12,500	--	--
Nebraska	6,950	49,300	--	--
Nevada	4,710	26,700	W	W
New Jersey	W	W	--	--
New Mexico	2,250	13,800	--	--
New York	31,900 [2]	267,000 [2]	10,200	86,500
North Carolina	W	W	W	W
Ohio	65,800 [2]	392,000 [2]	8,940	42,700
Oklahoma	38,500 [2]	232,000 [2]	--	--
Oregon	W	W	--	--
Pennsylvania	62,100 [2]	420,000 [2]	12,400	79,700
Rhode Island	W	W	--	--
South Carolina	W	W	--	--
South Dakota	3,200	14,800	--	--
Tennessee	62,900 [2]	474,000 [2]	W	W
Texas	129,000 [2]	792,000 [2]	W	W
Utah	3,550	19,400	W	W
Vermont	W [2]	W [2]	W	W
Virginia	29,000 [2]	260,000 [2]	3,400	27,900
Washington	2,120 [2]	13,100 [2]	W	W
West Virginia	13,200	89,800	--	--
Wisconsin	31,800 [2]	187,000 [2]	1,000	4,920
Wyoming	2,500 [2]	12,500 [2]	--	--
Other	24,700	199,000	17,800	138,000
Total	1,090,000	7,490,000	95,200	649,000

W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes limestone-dolomite reported with no distinction between the two kinds of stone.

[3]A significant amount of sold or used material was shipped in from other States.

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TABLE 9

CRUSHED GRANITE, TRAPROCK, AND SANDSTONE AND QUARTZITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY STATE[1]

(Thousand metric tons and thousand dollars)

State	Granite		Traprock		Sandstone and quartzite[2]	
	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	1,830	12,600	--	--	1,290	7,690
Alaska[3]	120	1,100	W	W	--	--
Arizona	3,650	21,900	W	W	597	6,790
Arkansas	9,320	59,600	--	--	10,500	56,100
California	13,700	122,000	11,600	115,000	3,810	24,300
Colorado	6,240	42,400	W	W	4,430	30,400
Connecticut	382	3,470	7,980	73,000	--	--
Florida	--	--	--	--	W	W
Georgia	66,900	509,000	--	--	2,110	16,100
Hawaii	--	--	5,420	72,000	--	--
Idaho	692	3,280	2,240	12,000	442	2,390
Illinois	--	--	--	--	125	1,200
Kansas	--	--	--	--	599	4,310
Louisiana[4]	--	--	--	--	W	W
Maine	1,730	12,400	W	W	520	3,470
Maryland	5,710	40,200	W	W	W	W
Massachusetts	3,850	30,900	7,830	68,600	--	--
Minnesota	2,690	22,100	--	--	419	3,570
Missouri	W	W	W	W	--	--
Montana	221	1,070	W	W	34	164
Nevada	3,130	22,500	--	--	--	--
New Hampshire	2,080	16,400	3,020	24,400	--	--
New Jersey	8,110	57,900	14,500	102,000	--	--
New Mexico	W	W	--	--	W	W
New York	3,540	28,400	W	W	2,330	22,200
North Carolina	53,900	472,000	7,690	62,400	W	W
North Dakota	W	W	10	43	--	--
Ohio	--	--	--	--	467	2,700
Oklahoma	3,740	23,900	--	--	2,530	16,600
Oregon	2	14	22,500	136,000	--	--
Pennsylvania	6,450	40,700	4,670	31,200	10,300	70,800
Rhode Island	455	3,930	1,150	8,510	--	--
South Carolina	25,200	203,000	--	--	--	--
South Dakota	241	1,110	--	--	3,210	14,800
Tennessee	515	3,880	--	--	W	W
Texas	W	W	W	W	857	7,420
Utah	--	--	--	--	1,350	7,730
Vermont	303	2,130	--	--	887	6,190
Virginia	31,200	291,000	18,600	164,000	2,180	19,900
Washington	539	3,890	9,300	62,400	W	W
West Virginia	--	--	--	--	1,260	9,620
Wisconsin	2,740	15,800	1,780	9,420	1,580	9,920
Wyoming	W	W	--	--	9	44
Other	3,740	88,900	11,700	96,300	3,420	42,600
Total	263,000	2,160,000	130,000	1,040,000	55,300	387,000

W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes sandstone-quartzite reported with no distinction between the two kinds of stone.

[3]Data derived, in part, from Alaska Division of Geological and Geophysical Surveys information.

[4]A significant amount of sold or used material was shipped in from other States.

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TABLE 10
CRUSHED CALCAREOUS MARL AND MARBLE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY STATE[1]

(Thousand metric tons and thousand dollars)

State	Calcareous marl		Marble	
	Quantity	Value	Quantity	Value
Alabama	--	--	2,750	18,200
Arizona	--	--	67	361
California	--	--	W	W
Colorado	--	--	W	W
Georgia	--	--	1,740	14,100
Michigan	W	W	--	--
New York	--	--	W	W
Pennsylvania	--	--	W	W
South Carolina	4,920	28,200	W	W
Texas	W	W	55	1,160
Vermont	--	--	2,030	13,700
Washington	--	--	217	1,520
Wyoming	--	--	W	W
Other	24	138	910	9,740
Total	4,950	28,300	7,760	58,700

W Withheld to avoid disclosing company proprietary data, included in "Other." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 11
CRUSHED VOLCANIC CINDER AND SCORIA AND CRUSHED MISCELLANEOUS STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY STATE[1]

(Thousand metric tons and thousand dollars)

State	Volcanic cinder and scoria		Miscellaneous stone	
	Quantity	Value	Quantity	Value
Alabama	--	--	50	436
Alaska[2]	--	--	2,140	13,600
Arizona	151	813	1,250	6,180
Arkansas	--	--	676	4,140
California	176	1,810	2,270	22,400
Colorado	159	1,080	583	3,590
Connecticut	--	--	1	5
Hawaii	W	W	419	4,320
Idaho	--	--	546	2,570
Maine	--	--	W	W
Maryland	--	--	--	--
Massachusetts	--	--	W	W
Michigan	--	--	W	W
Montana	W	W	254	1,010
Nevada	W	W	1,060	6,580
New Jersey	--	--	W	W
New Mexico	338	2,620	240	1,820
New York	--	--	327	2,430
North Carolina	--	--	3,460	33,500
North Dakota	42	186	15	64
Oklahoma	--	--	584	3,110
Oregon	47	261	2,180	12,700
Pennsylvania	--	--	8,870	57,800
Texas	27	51	1,760	9,880
Utah	W	W	536	3,370
Virginia	--	--	1,640	13,500
Washington	W	W	1,050	7,300
Wyoming	W	W	1,560	8,240
Other	2,020	14,600	1,520	7,230
Total	2,960	21,400	33,000	226,000

W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Data derived, in part, from Alaska Division of Geological and Geophysical Surveys information.

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TABLE 12

KIND OF CRUSHED STONE PRODUCED AND/OR DISTRIBUTED IN THE UNITED STATES IN 2005, BY STATE

State	Limestone	Dolomite	Marble	Calcareous marl	Shell	Granite	Traprock	Sandstone	Quartzite	Slate	Volcanic cinder and scoria	Miscellaneous
Alabama	X	X	X			X		X		X		X
Alaska[1]					X	X	X					X
Arizona	X		X			X	X	X	X		X	X
Arkansas	X	X				X		X	X	X		X
California	X	X	X		X	X	X	X	X	X	X	X
Colorado	X	X	X			X	X	X	X		X	X
Connecticut	X	X				X	X					X
Delaware	X											
Florida	X	X			X			X				
Georgia	X		X			X			X			
Hawaii	X						X				X	X
Idaho	X				X	X	X		X			X
Illinois	X	X						X				X
Indiana	X	X										
Iowa	X	X										
Kansas	X								X			
Kentucky	X	X										
Louisiana	X							X				X
Maine	X					X	X		X	X		X
Maryland	X				X	X	X	X				
Massachusetts	X	X				X	X					X
Michigan	X	X		X								X
Minnesota	X	X				X			X			
Mississippi	X											
Missouri	X	X				X	X					
Montana	X					X	X	X			X	X
Nebraska	X											
Nevada	X	X				X					X	X
New Hampshire						X	X					
New Jersey	X					X	X					X
New Mexico	X					X		X			X	X
New York	X	X	X			X	X	X		X		X
North Carolina	X	X				X	X		X	X		X
North Dakota						X	X				X	X
Ohio	X	X						X				
Oklahoma	X					X		X	X			X
Oregon	X					X	X				X	X
Pennsylvania	X	X	X			X	X	X	X	X		X
Rhode Island	X					X	X					
South Carolina	X		X	X		X						
South Dakota	X					X			X	X		
Tennessee	X	X				X		X				
Texas	X	X	X	X	X	X	X	X	X		X	X
Utah	X	X						X	X		X	X
Vermont	X	X	X			X			X	X		
Virginia	X	X				X	X	X	X	X		X
Washington	X	X	X			X	X	X		X	X	X
West Virginia	X							X				
Wisconsin	X	X				X	X	X				
Wyoming	X		X			X			X		X	X

[1]Data derived, in part, from Alaska Division of Geological and Geophysical Surveys information.

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TABLE 13
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY USE[1]

Use	Quantity (thousand metric tons)	Value (thousands)	Unit value
Construction:			
Coarse aggregate (+1½ inch):			
Macadam	5,100	$35,700	$7.01
Riprap and jetty stone	15,000	152,000	10.19
Filter stone	8,920	82,200	9.21
Other coarse aggregate	16,900	119,000	7.06
Coarse aggregate, graded:			
Concrete aggregate, coarse	80,200	669,000	8.34
Bituminous aggregate, coarse	65,200	518,000	7.94
Bituminous surface-treatment aggregate	15,000	134,000	8.93
Railroad ballast	9,000	61,800	6.86
Other graded coarse aggregate	87,800	747,000	8.51
Fine aggregate (-$^3/_8$ inch):			
Stone sand, concrete	21,200	155,000	7.34
Stone sand, bituminous mix or seal	15,500	98,800	6.37
Screening, undesignated	16,800	120,000	7.12
Other fine aggregate	35,500	281,000	7.93
Coarse and fine aggregates:			
Graded road base or subbase	147,000	907,000	6.17
Unpaved road surfacing	24,300	155,000	6.38
Terrazzo and exposed aggregate	1,120	16,300	14.55
Crusher run or fill or waste	26,300	149,000	5.69
Roofing granules	1,700	73,800	43.32
Other coarse and fine aggregates	109,000	750,000	6.87
Other construction materials[2]	10,600	104,000	9.87
Agricultural:			
Agricultural limestone	10,800	64,200	5.94
Poultry grit and mineral food	1,060	11,400	10.76
Other agricultural uses	1,200	18,300	15.24
Chemical and metallurgical:			
Cement manufacture	76,100	349,000	4.58
Lime manufacture	18,600	134,000	7.21
Dead-burned dolomite manufacture	W	W	5.73
Flux stone	4,360	22,800	5.24
Chemical stone	334	5,890	17.64
Glass manufacture	1,180	11,500	9.76
Sulfur oxide removal	3,610	22,000	6.09
Special:			
Mine dusting or acid water treatment	208	4,550	21.87
Asphalt fillers or extenders	1,160	15,400	13.29
Whiting or whiting substitute	103	1,280	12.44
Other fillers or extenders	4,330	66,100	15.27
Other miscellaneous uses:			
Chemicals	34	1,120	32.94
Refractory stone	W	W	2.00
Sugar refining	224	1,240	5.54
Waste material	W	W	2.00
Other specified uses not listed	5,500	42,500	7.73
Unspecified:[3]			
Reported	540,000	3,830,000	7.09
Estimated	304,000	2,170,000	7.13
Total or average	1,690,000	12,100,000	7.18

See footnotes at end of table.

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TABLE 13—Continued
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES
IN 2005, BY USE[1]

W Withheld to avoid disclosing company proprietary data; included in "Total or average."
[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.
[2]Includes building products, drain fields, and pipe bedding.
[3]Reported and estimated production without a breakdown by end use.

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TABLE 14
CRUSHED LIMESTONE AND DOLOMITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY USE[1]

(Thousand metric tons and thousand dollars)

Use	Limestone[2]		Dolomite	
	Quantity	Value	Quantity	Value
Construction:				
Coarse aggregate (+1½ inch):				
Macadam	2,500	17,500	1,560	12,100
Riprap and jetty stone	8,040	62,700	1,590	16,200
Filter stone	5,190	48,000	1,720	12,800
Other coarse aggregate	13,000	89,300	524	3,680
Coarse aggregate, graded:				
Concrete aggregate, coarse	43,200	327,000	6,050	43,100
Bituminous aggregate, coarse	42,100	311,000	5,000	40,200
Bituminous surface-treatment aggregate	6,830	61,700	3,310	25,700
Railroad ballast	1,730	10,400	988	6,590
Other graded coarse aggregate	70,800	600,000	3,100	17,300
Fine aggregate (-$^3/_8$ inch):				
Stone sand, concrete	9,720	62,800	1,370	7,920
Stone sand, bituminous mix or seal	8,260	50,200	1,680	9,080
Screening, undesignated	9,990	72,400	1,340	6,540
Other fine aggregate	29,300	238,000	1,060	6,690
Coarse and fine aggregates:				
Graded road base or subbase	94,000	520,000	9,290	57,200
Unpaved road surfacing	18,000	114,000	3,110	20,000
Terrazzo and exposed aggregate	65	789	--	--
Crusher run or fill or waste	17,600	93,300	2,080	12,400
Roofing granules	427	3,370	--	--
Other coarse and fine aggregates	78,700	547,000	6,540	37,400
Other construction materials[3]	4,940	54,000	641	6,370
Agricultural:				
Agricultural limestone	9,660	56,400	1,160	7,770
Poultry grit and mineral food	1,030	10,900	--	--
Other agricultural uses	795	8,260	W	W
Chemical and metallurgical:				
Cement manufacture	70,900	329,000	--	--
Lime manufacture	17,500	130,000	1,120	4,330
Dead-burned dolomite manufacture	--	--	W	W
Flux stone	1,690	9,980	2,340	10,800
Chemical stone	W	W	--	--
Glass manufacture	491	3,450	W	W
Sulfur oxide removal	3,610	22,000	--	--
Special:				
Mine dusting or acid water treatment	205	4,480	--	--
Asphalt fillers or extenders	674	7,340	W	W
Whiting or whiting substitute	79	1,100	W	W
Other fillers or extenders	3,240	57,900	W	W
Other miscellaneous uses:				
Chemicals	34	1,120	--	--
Refractory stone (including ganister)	W	W	--	--
Sugar refining	224	1,240	--	--
Waste material	W	W	--	--
Other specified uses not listed	2,620	17,200	216	1,000
Unspecified:[4]				
Reported	294,000	2,020,000	29,000	192,000
Estimated	214,000	1,520,000	8,440	66,000
Total or average	1,090,000	7,490,000	95,200	649,000

See footnotes at end of table.

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TABLE 14—Continued
CRUSHED LIMESTONE AND DOLOMITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY USE[1]

W Withheld to avoid disclosing company proprietary data; included in "Total or average."
-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes a minor amount of limestone-dolomite reported without a distinction between the two.
[3]Includes building products, drain fields, and pipe bedding.
[4]Reported and estimated production without a breakdown by end use.

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TABLE 15

CRUSHED LIMESTONE AND DOLOMITE SOLD OR USED BY PRODUCERS IN 2005, BY STATE AND USE[1]

(Thousand metric tons and thousand dollars)

State	Concrete aggregate		Bituminous aggregate		Roadstone and coverings		Riprap and railroad ballast		Other construction uses	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	3,290	19,700	10,400	68,400	2,990	18,400	211	1,500	7,790	52,900
Arizona	--	--	--	--	--	--	--	--	W	W
Arkansas	1,050	8,360	951	8,180	2,680	17,700	210	1,370	2,240	12,300
California	W	W	373	5,750	273	2,230	218	5,450	1,400	12,000
Colorado	W	W	W	W	W	W	W	W	--	--
Connecticut	W	W	W	W	W	W	--	--	W	W
Delaware	--	--	--	--	--	--	--	--	--	--
Florida	13,200	149,000	14,000	187,000	14,100	69,400	47	835	13,800	123,000
Georgia	W	W	W	W	W	W	W	W	W	W
Hawaii	--	--	W	W	--	--	--	--	W	W
Idaho	--	--	--	--	W	W	--	--	--	--
Illinois	12,300	92,500	12,300	98,900	16,000	91,400	2,480	25,000	6,690	40,700
Indiana	5,490	26,400	6,930	37,700	11,800	68,600	1,280	8,240	5,130	28,300
Iowa	1,110	10,500	852	6,400	4,730	31,800	95	1,100	1,610	11,700
Kansas	W	W	587	4,160	1,660	8,430	220	1,610	1,350	9,090
Kentucky	4,490	27,500	7,840	58,300	5,420	41,200	575	4,090	8,120	57,300
Louisiana[2]	W	W	W	W	W	W	--	--	W	W
Maine	W	W	--	--	W	W	33	282	316	2,540
Maryland	1,840	19,700	3,990	46,400	2,840	20,900	366	2,600	2,940	23,800
Massachusetts	--	--	--	--	W	W	--	--	W	W
Michigan	4,690	22,100	2,090	11,100	2,060	10,500	148	2200	979	4,060
Minnesota	W	W	W	W	970	7,620	62	1210	118	974
Mississippi[2]	W	W	W	W	W	W	--	--	W	W
Missouri	4,680	35,800	7,340	50,600	7,140	37,000	1,710	6,410	10,900	68,200
Montana	W	W	--	--	W	W	W	W	W	W
Nebraska	W	W	W	W	W	W	W	W	W	W
Nevada	--	--	--	--	--	--	--	--	W	W
New Jersey	W	W	--	--	W	W	--	--	--	--
New Mexico	54	482	W	W	68	447	W	W	W	W
New York	3,430	30,300	6,550	65,400	4,050	26,200	257	2,340	6,680	57,600
North Carolina	W	W	W	W	W	W	W	W	W	W
Ohio	2,380	10,800	5,930	30,600	20,500	127,000	556	3,110	2,680	14,600
Oklahoma	1,320	8,080	12,400	72,600	1,670	8,580	420	3,050	10,300	46,300
Oregon	--	--	--	--	--	--	--	--	--	--
Pennsylvania	4,990	34,500	13,600	96,600	7,410	48,700	906	6,640	8,660	51,500
Rhode Island	--	--	--	--	--	--	--	--	--	--
South Carolina	W	W	W	W	W	W	--	--	W	W
South Dakota	W	W	W	W	W	W	--	--	W	W
Tennessee	3,530	30,000	17,800	138,000	9,720	59,800	1,290	8,890	10,700	76,200
Texas	14,700	97,000	7,400	56,800	14,500	71,500	497	3,580	15,300	97,300
Utah	--	--	--	--	W	W	--	--	W	W
Vermont	W	W	W	W	W	W	--	--	W	W
Virginia	1,620	13,400	3,860	28,500	1,710	12,600	284	2,620	3,780	29,600
Washington	--	--	W	W	W	W	--	--	W	W
West Virginia	869	5,390	756	5,090	780	4,670	102	738	1,230	8,500
Wisconsin	1,270	7,870	658	3,340	6,290	31,900	171	986	1,810	17,300
Wyoming	--	--	W	W	W	W	--	--	W	W
Total	86,300	650,000	137,000	1,080,000	139,000	817,000	12,100	93,800	125,000	846,000
Total withheld	4,390	34,900	5,680	50,700	2,660	17,700	199	2,080	4,630	48,900
Grand total	90,700	685,000	142,000	1,130,000	142,000	834,000	12,300	95,900	129,000	894,000

See footnotes at end of table.

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TABLE 15—Continued

CRUSHED LIMESTONE AND DOLOMITE SOLD OR USED BY PRODUCERS IN 2005, BY STATE AND USE[1]

(Thousand metric tons and thousand dollars)

State	Cement manufacture		Agricultural uses		Lime manufacture		Other uses		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	2,640	14,900	W	W	W	W	13,200	89,500	(3)	(3)
Arizona	W	W	W	W	W	W	2,270	12,200	6,340 [4]	33,200 [4]
Arkansas	W	W	241	2,010	W	W	5,300	34,700	(3, 4)	(3, 4)
California	6,870	33,300	176	3,610	--	--	13,000	104,000	22,400 [4]	166,000 [4]
Colorado	--	--	W	W	--	--	741	6,540	(3)	(3)
Connecticut	--	--	--	--	--	--	1,610	14,800	(3, 4)	(3, 4)
Delaware	--	--	--	--	--	--	W	W	(3)	(3)
Florida	6,150	18,200	620	5,080	--	--	48,900	418,000	111,000 [4]	970,000 [4]
Georgia	W	W	W	W	--	--	4,000	29,900	8,690	66,900
Hawaii	--	--	--	--	--	--	--	--	(3)	(3)
Idaho	W	W	W	W	--	--	W	W	(3)	(3)
Illinois	W	W	2,420	8,490	W	W	20,800	165,000	76,000 [4]	544,000 [4]
Indiana	W	W	1,660	7,340	--	--	22,300	126,000	57,500 [4]	311,000 [4]
Iowa	--	--	W	W	W	W	24,800	179,000	(3, 4)	(3, 4)
Kansas	3,260	28,600	188	618	--	--	13,900	100,000	21,500	155,000
Kentucky	--	--	W	W	W	W	28,500	206,000	(3, 4)	(3, 4)
Louisiana[2]	--	--	--	--	--	--	W	W	(3)	(3)
Maine	W	W	--	--	W	W	W	W	1,940	12,500
Maryland	W	W	W	W	--	--	6,660	51,200	21,400 [4]	181,000 [4]
Massachusetts	--	--	W	W	W	W	337	7,810	(3, 4)	(3, 4)
Michigan	W	W	103	971	W	W	20,100	78,800	35,200	139,000
Minnesota	--	--	38	234	--	--	6,150	51,000	(3, 4)	(3, 4)
Mississippi[2]	W	W	W	W	--	--	1,110	8,170	3,500	41,700
Missouri	4,160	16,300	857	3,750	1,850	8,670	58,500	431,000	97,200 [4]	657,000 [4]
Montana	W	W	W	W	W	W	1,260	5,800	2,550	12,500
Nebraska	W	W	W	W	--	--	4,410	31,500	6,950	49,300
Nevada	W	W	W	W	W	W	2,810	17,300	(3)	(3)
New Jersey	--	--	--	--	--	--	--	--	(3)	(3)
New Mexico	--	--	--	--	--	--	1,740	11,600	2,250	13,800
New York	--	--	W	W	W	W	20,600	168,000	42,100 [4]	353,000 [4]
North Carolina	--	--	--	--	--	--	W	W	(3)	(3)
Ohio	W	W	625	3,810	W	W	37,000	219,000	74,700 [4]	435,000 [4]
Oklahoma	W	W	123	761	W	W	9,900	57,500	38,500 [4]	214,000 [4]
Oregon	W	W	--	--	--	--	W	W	(3)	(3)
Pennsylvania	3,270	23,500	W	W	W	W	35,000	231,000	74,600 [4]	499,000 [4]
Rhode Island	--	--	W	W	--	--	W	W	(3)	(3)
South Carolina	--	--	--	--	--	--	2,810	20,200	3,700	26,200
South Dakota	W	W	--	--	W	W	W	W	3,200	14,800
Tennessee	W	W	251	2,070	W	W	18,500	142,000	(3, 4)	(3, 4)
Texas	12,000	43,600	W	W	W	W	64,200	418,000	(3, 4)	(3, 4)
Utah	W	W	57	1,010	W	W	3,320	18,800	(3)	(3)
Vermont	--	--	--	--	--	--	1,990	13,400	(3, 4)	(3, 4)
Virginia	--	--	W	W	W	W	20,400	187,000	32,400 [4]	288,000 [4]
Washington	W	W	W	W	W	W	1,290	8,740	(3, 4)	(3, 4)
West Virginia	--	--	W	W	--	--	W	W	13,200	89,800
Wisconsin	--	--	W	W	W	W	22,200	127,000	32,800 [4]	192,000 [4]
Wyoming	--	--	--	--	--	--	2,480	12,300	2,500 [4]	12,500 [4]
Total	38,300	179,000	7,350	39,700	1,850	8,670	542,000	3,800,000	XX	XX
Total withheld	32,600	150,000	1,580	24,500	13,500	128,000	19,300	135,000	XX	XX
Grand total	70,900	329,000	8,930	64,300	15,300	136,000	561,000	3,940,000	1,180,000	8,130,000

W Withheld to avoid disclosing company proprietary data; included in "Total" or "Total withheld." XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 16
CRUSHED MARBLE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY USE[1]

(Thousand metric tons and thousand dollars)

Use	Quantity	Value
Construction:		
Coarse aggregate (+1½ inch):		
Macadam	46	343
Riprap and jetty stone	320	3,850
Filter stone	W	W
Coarse aggregate, graded:		
Concrete aggregate, coarse	W	W
Bituminous aggregate, coarse	W	W
Bituminous surface-treatment aggregate	18	110
Other graded coarse aggregate	2	26
Fine aggregate (-$^3/_8$ inch):		
Stone sand, concrete	W	W
Stone sand, bituminous mix or seal	W	W
Screening, undesignated	W	W
Coarse and fine aggregates:		
Graded road base or subbase	W	W
Terrazzo and exposed aggregate	W	W
Crusher run or fill or waste	16	34
Other coarse and fine aggregates	1,670	11,900
Agricultural:		
Poultry grit and mineral food	1	61
Other agricultural uses	240	830
Special:		
Mine dusting or acid water treatment	W	W
Other fillers or extenders	566	4,400
Other miscellaneous uses and other specified uses not listed	39	2,490
Unspecified, estimated[2]	4,010	27,400
Total	7,760	58,700

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Estimated production without a breakdown by end use.

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TABLE 17
CRUSHED GRANITE AND TRAPROCK SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY USE[1]

(Thousand metric tons and thousand dollars)

Use	Granite		Traprock	
	Quantity	Value	Quantity	Value
Construction:				
Coarse aggregate (+1 ½ inch):				
Macadam	591	3,130	300	1,760
Riprap and jetty stone	3,460	43,500	685	10,800
Filter stone	766	8,710	864	9,190
Other coarse aggregate	1,000	9,560	1,370	8,490
Coarse aggregate, graded:				
Concrete aggregate, coarse	24,400	237,000	4,170	41,100
Bituminous aggregate, coarse	12,800	120,000	3,040	27,400
Bituminous surface-treatment aggregate	2,860	29,400	1,570	13,300
Railroad ballast	3,570	25,400	2,210	15,000
Other graded coarse aggregate	6,680	64,400	3,750	37,000
Fine aggregate (-$^3/_8$ inch):				
Stone sand, concrete	8,530	61,200	761	15,200
Stone sand, bituminous mix or seal	3,450	22,500	1,070	9,810
Screening, undesignated	3,190	24,900	1,750	12,400
Other fine aggregate	2,230	12,500	696	7,320
Coarse and fine aggregates:				
Graded road base or subbase	25,800	195,000	12,400	95,600
Unpaved road surfacing	1,060	7,710	1,550	9,330
Terrazzo and exposed aggregate	584	8,160	32	348
Crusher run or fill or waste	3,100	20,300	2,220	14,900
Roofing granules	627	67,800	W	W
Other coarse and fine aggregates	7,550	50,100	9,050	66,100
Other construction materials[2]	9	74	1,810	24,800
Agricultural:				
Poultry grit and mineral food	5	286	--	--
Other agricultural uses	18	80	--	--
Special:				
Asphalt fillers or extenders	--	--	W	W
Other fillers or extenders	--	--	W	W
Other miscellaneous uses and specified uses not listed	536	8,660	106	1,380
Unspecified:[3]				
Reported	119,000	910,000	58,800	462,000
Estimated	31,000	228,000	21,500	153,000
Total	263,000	2,160,000	130,000	1,040,000

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes drain fields and pipe bedding.

[3]Reported and estimated production without a breakdown by end use.

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TABLE 18
CRUSHED SANDSTONE AND QUARTZITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY USE[1,2]

(Thousand metric tons and thousand dollars)

Use	Sandstone		Quartzite	
	Quantity	Value	Quantity	Value
Construction:				
Coarse aggregate (+1½ inch):				
Macadam	W	W	--	--
Riprap and jetty stone	527	8,230	16	200
Filter stone	214	1,670	W	W
Other coarse aggregate	448	3,550	110	773
Coarse aggregate, graded:				
Concrete aggregate, coarse	876	6,420	144	1,100
Bituminous aggregate, coarse	977	7,700	421	5,060
Bituminous surface-treatment aggregate	174	1,380	W	W
Railroad ballast	W	W	W	W
Other graded coarse aggregate	1,310	11,600	325	2,140
Fine aggregate (-$^3/_8$ inch):				
Stone sand, concrete	485	3,910	W	W
Stone sand, bituminous mix or seal	625	4,290	80	690
Screening, undesignated	254	1,510	--	--
Other fine aggregate	1,140	9,140	457	3,760
Coarse and fine aggregates:				
Graded road base or subbase	2,250	14,900	525	4,170
Unpaved road surfacing	38	327	W	W
Terrazzo and exposed aggregate	--	--	W	W
Crusher run or fill or waste	469	2,460	W	W
Roofing granules	W	W	--	--
Other coarse and fine aggregates	1,710	12,200	440	2,130
Other construction materials[3]	98	865	--	--
Chemical and metallurgical:				
Cement manufacture	W	W	W	W
Flux stone	W	W	W	W
Glass manufacture	W	W	--	--
Special, other fillers or extenders	W	W	--	--
Other miscellaneous uses:				
Abrasives	(4)	(4)	--	--
Other specified uses not listed	275	3,080	158	2,100
Unspecified:[5]				
Reported	14,000	95,700	9,460	59,400
Estimated	10,900	71,800	2,310	17,600
Total	37,200	267,000	18,100	120,000

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes sandstone-quartzite reported with no distinction between the two kinds of stone.

[3]Includes drain fields.

[4]Less than ½ unit.

[5]Reported and estimated production without a breakdown by end use.

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TABLE 19
CRUSHED VOLCANIC CINDER AND SCORIA AND CRUSHED MISCELLANEOUS STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005, BY USE[1]

(Thousand metric tons and thousand dollars)

Use	Volcanic cinder and scoria		Miscellaneous stone	
	Quantity	Value	Quantity	Value
Construction:				
Coarse aggregate (+1½ inch):				
Macadam	--	--	W	W
Riprap and jetty stone	(2)	5	328	6,720
Filter stone	--	--	132	1,510
Other coarse aggregate	91	1,040	371	2,900
Coarse aggregate, graded:				
Concrete aggregate, coarse	200	1,830	1,120	11,900
Bituminous aggregate, coarse	--	--	571	4,020
Bituminous surface-treatment aggregate	--	--	155	1,480
Railroad ballast	--	--	448	3,940
Other graded coarse aggregate	--	--	1,570	12,500
Fine aggregate (-$^3/_8$ inch):				
Stone sand, concrete	W	W	90	765
Stone sand, bituminous mix or seal	--	--	340	2,230
Screening, undesignated	W	W	254	2,010
Other fine aggregate	2	24	503	3,500
Coarse and fine aggregates:				
Graded road base or subbase	48	623	1,690	13,100
Unpaved road surfacing	--	--	493	2,650
Terrazzo and exposed aggregate	W	W	W	W
Crusher run or fill or waste	52	486	487	3,640
Other coarse and fine aggregates	233	1,830	1,930	11,100
Other construction materials	28	55	802	7,120
Agricultural, other agricultural uses	W	W	W	W
Chemical and metallurgical, cement manufacture	--	--	69	384
Special, other fillers or extenders	--	--	W	W
Other miscellaneous uses and other specified uses not listed	319	2,280	1,150	3,590
Unspecified:[3]				
Reported	1,580	8,230	12,300	72,400
Estimated	286	1,840	8,200	57,900
Total	2,960	21,400	33,000	226,000

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

[3]Reported and estimated production without a breakdown by end use.

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TABLE 20
RECYCLED ASPHALT SOLD OR USED BY PRODUCERS IN THE UNITED STATES,
BY GEOGRAPHIC DIVISION[1]

	2004			2005		
Region/division	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
Northeast:						
New England	171 r	$963 r	$5.63 r	143	$944	$6.60
Middle Atlantic	684 r	5,500 r	8.04 r	448	2,690	6.00
Midwest:						
East North Central	260	1,710	6.57	253	1,580	6.24
West North Central	329	1,790	5.45	45	300	6.67
South:						
South Atlantic	357	2,360	6.62	329	2,190	6.65
East South Central	72	781	10.85	--	--	--
West South Central	143	770	5.38	170	2,350	13.82
West:						
Mountain	9	57	6.33	1	8	8.00
Pacific	311	2,130	6.84	548	7,610	13.89
Total or average	2,340 r	16,100 r	6.88 r	1,940	17,700	9.12

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.

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TABLE 21

RECYCLED ASPHALT SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

State	2004			2005		
	Quantity (thousand metric tons)	Value (thousands)	Unit value	Quantity (thousand metric tons)	Value (thousands)	Unit value
Alabama	45	$250	$5.55	--	--	--
Alaska	2	33	16.50	24	$138	$5.75
California	211	1,150	5.45	433	6,610	15.27
Connecticut	38	187	4.92	58	329	5.67
Florida	357	2,360	6.62	329	2,190	6.65
Hawaii	73	800	10.95	73	800	10.95
Illinois	107	687	6.42	5	18	3.60
Indiana	42	459	10.93	172	1,150	6.67
Iowa	1	5	5.00	--	--	--
Kansas	(2)	3	3.00	45	300	6.67
Kentucky	27	531	19.66	--	--	--
Louisiana[3]	20	167	8.35	9	84	9.33
Maine	104	616	5.92	79	573	7.25
Massachusetts	19	90	4.74	--	--	--
Michigan	--	--	--	5	25	5.00
Minnesota	56	298	5.32	--	--	--
Missouri	253	1,390	5.50	--	--	--
Nevada	9	57	6.33	--	--	--
New Jersey	342	1,890	5.52	69	230	3.33
New Mexico	--	--	--	1	8	8.00
New York	142	1,270	8.93	177	1,100	6.21
Oklahoma	--	--	--	86	461	5.36
Oregon	20	107	5.35	3	16	5.33
Pennsylvania	198 r	2,340 r	11.81 r	202	1,360	6.74
South Dakota	18	96	5.33	--	--	--
Texas	123	603	4.90	74	1,800	24.38
Vermont	11	70	6.36	6	42	7.00
Washington	6	35	5.83	15	48	3.20
Wisconsin	112	563	5.02	72	388	5.39
Total or average	2,340 r	16,100 r	6.88 r	1,940	17,700	9.12

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.

[2]Less than ½ unit.

[3]A significant amount of sold or used material was shipped in from other States.

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TABLE 22
RECYCLED CONCRETE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY GEOGRAPHIC DIVISION[1]

Region/division	2004 Quantity (thousand metric tons)	2004 Value (thousands)	2004 Unit value	2005 Quantity (thousand metric tons)	2005 Value (thousands)	2005 Unit value
Northeast:						
New England	60	$296	$4.93	36	$200	$5.56
Middle Atlantic	178	993	5.58	220	1,300	5.90
Midwest:						
East North Central	1,390 r	8,490 r	6.09 r	1,670	10,400	6.24
West North Central	158	784	4.96	20	107	5.35
South:						
South Atlantic	423	3,540	8.37	320	2,840	8.86
West South Central	109	524	4.81	12	119	9.92
West:						
Mountain	--	--	--	24	103	4.29
Pacific	490	3,490	7.11	1,560	14,300	9.20
Total or average	2,810 r	18,100 r	6.44 r	3,860	29,400	7.62

rRevised. -- Zero.
[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.

TABLE 23
RECYCLED CONCRETE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

State	2004 Quantity (thousand metric tons)	2004 Value (thousands)	2004 Unit value	2005 Quantity (thousand metric tons)	2005 Value (thousands)	2005 Unit value
Alaska	5	$58	$11.60	--	--	--
California	352	2,200	6.24	1,540	$14,200	$9.19
Colorado	--	--	--	24	103	4.29
Connecticut	36	191	5.31	17	101	5.94
Florida	152	1,330	8.76	10	54	5.40
Hawaii	96	1,040	10.78	12	128	10.67
Illinois	1,070 r	6,280 r	5.86 r	1,560	9,830	6.30
Indiana	50	276	5.52	--	--	--
Louisiana[2]	5	36	7.20	12	119	9.92
Maine	11	50	4.55	13	71	5.46
Massachusetts	13	55	4.23	6	28	4.67
Michigan	--	--	--	5	25	5.00
Minnesota	138	682	4.94	20	107	5.35
New Jersey	61	395	6.48	16	60	3.75
New York	113	568	5.03	182	1,080	5.92
North Carolina	1	7 r	7.00 r	--	--	--
Ohio	--	--	--	9	42	4.67
Oregon	18	101	5.61	4	24	6.00
Pennsylvania	5	29	5.80	23	161	7.00
South Carolina	--	--	--	4	20	5.00
South Dakota	21	102	4.86	--	--	--
Texas	104	488	4.69	--	--	--
Virginia	271	2,210	8.14	305	2,760	9.06
Washington	19	94	4.95	--	--	--
Wisconsin	270	1,930	7.14	94	512	5.45
Total or average	2,810 r	18,100 r	6.44 r	3,860	29,400	7.62

rRevised. -- Zero.
[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.
[2]A significant amount of sold or used material was shipped in from other States.

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TABLE 24
CRUSHED STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES IN 2005,
BY GEOGRAPHIC DIVISION AND METHOD OF TRANSPORTATION[1]

(Thousand metric tons)

Region/division	Truck	Rail	Water	Other	Not transported	Not specified	Total
Northeast:							
New England	3,710	42	--	--	2,760	33,500	40,000
Middle Atlantic	72,000	2,160	--	--	6,730	100,000	181,000
Midwest:							
East North Central	112,000	9,990	8,950	876	9,070	143,000	284,000
West North Central	50,300	2,660	5,220	1,510	3,370	117,000	180,000
South:							
South Atlantic	194,000	10,800	2,640	3,480	7,420	220,000	438,000
East South Central	96,900	2,670	2,900	1,320	4,400	68,100	176,000
West South Central	83,100	14,800	3,390	--	9,010	112,000	223,000
West:							
Mountain	24,000	886	--	2,630	2,830	30,800	61,200
Pacific	33,600	4,700	722	1,850	3,300	58,600	103,000
Total	669,000	48,700	23,800	11,700	48,900	883,000	1,690,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

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TABLE 25
CRUSHED AND BROKEN STONE OPERATIONS IN THE UNITED STATES IN 2005, BY STATE

State	Active operations	Active quarries	Dredging operations	Processing plants				Sales yards
				Stationary	Portable	Stationary and portable	None or unspecified	
Alabama	82	71	--	61	6	3	1	11
Alaska[1]	14	15	--	1	8	1	3	1
Arizona	40	38	--	16	15	6	2	1
Arkansas	56	54	--	28	15	6	5	2
California	124	137	1	77	27	11	7	1
Colorado	36	36	--	19	9	5	3	--
Connecticut	23	22	--	17	4	1	--	1
Delaware	4	--	--	--	--	--	--	4
Florida	101	93	1	31	37	13	5	14
Georgia	82	78	1	71	3	--	2	5
Hawaii	21	24	--	10	10	1	--	--
Idaho	37	41	--	5	26	3	3	--
Illinois	122	123	--	74	34	6	--	8
Indiana	91	88	--	70	6	7	4	4
Iowa	184	198	--	27	148	1	3	5
Kansas	98	116	--	18	75	4	1	--
Kentucky	91	88	--	70	6	11	1	3
Louisiana	19	--	--	--	--	--	--	19
Maine	18	16	--	11	5	--	--	2
Maryland	26	25	1	16	4	2	1	2
Massachusetts	33	31	--	19	6	6	--	2
Michigan	34	33	--	19	9	1	3	2
Minnesota	37	47	--	8	23	1	5	--
Mississippi	16	4	--	2	1	1	--	12
Missouri	175	175	--	100	55	11	4	1
Montana	22	23	--	5	15	--	2	--
Nebraska	9	9	--	6	2	1	--	--
Nevada	17	17	--	14	2	--	--	--
New Hampshire	14	14	--	13	1	--	--	--
New Jersey	24	23	--	12	2	8	--	1
New Mexico	28	28	--	10	15	3	2	--
New York	98	98	1	78	10	6	2	--
North Carolina	109	101	--	90	9	2	1	7
North Dakota	4	4	--	--	2	--	2	--
Ohio	111	107	--	77	17	3	4	4
Oklahoma	55	55	--	41	4	7	2	--
Oregon	125	136	--	35	80	2	7	1
Pennsylvania	187	187	--	147	16	14	10	--
Rhode Island	7	7	--	7	--	--	--	--
South Carolina	36	31	--	27	--	2	1	6
South Dakota	12	12	--	9	2	1	--	--
Tennessee	117	113	--	101	6	--	3	7
Texas	149	124	--	75	30	9	6	29
Utah	25	27	--	11	12	1	1	--
Vermont	14	14	--	8	3	2	1	--
Virginia	113	96	--	83	4	5	1	19
Washington	90	125	--	25	45	6	12	2
West Virginia	36	32	--	24	1	3	2	6
Wisconsin	132	219	--	30	86	4	6	2
Wyoming	16	16	--	7	7	1	1	--
Total	3,114	3,171	5	1,705	903	181	119	184

-- Zero.

[1]Data derived, in part, from Alaska Division of Geological and Geophysical Surveys.

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TABLE 26

U.S. EXPORTS OF CRUSHED STONE IN 2005, BY DESTINATION[1]

Destination		Limestone	Limestone for cement manufacturing	Chalk, crude	Granules, chippings	Other	Total
North America	metric tons	48,100	630,000	2,840	91,500	386,000	1,160,000
South America	do.	2	33	10,100	2,340	237	12,700
Europe	do.	119	10,300	61	3,090	32,400	46,000
Asia	do.	55	15,300	96	9,880	17,100	42,400
Oceania	do.	18	40	26	19	220	323
Middle East	do.	--	12	2	3,760	255	4,020
Africa	do.	--	--	--	--	76	76
Total:							
Quantity	do.	48,300	656,000	13,100	111,000	437,000	1,260,000
Value	thousands	$1,210	$13,600 [2]	$4 [2]	$13,700	$22,000	$50,500

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]All or part of these data have been referred to the U.S. Census Bureau for verification.

Source: U.S. Census Bureau.

TABLE 27

U.S. IMPORTS OF CRUSHED STONE AND CALCIUM CARBONATE FINES, BY TYPE[1]

Type	2004			2005		
	Quantity (thousand) metric tons)	Value, c.i.f.[2] (thousands)	Unit value	Quantity (thousand) metric tons)	Value, c.i.f.[2] (thousands)	Unit value
Crushed stone and chips:						
Limestone	7,670	$65,700	$8.56	7,860	$59,300	$7.54
Limestone for flux or cement manufacturing	4,710	37,000	7.85	4,100	38,100	9.29
Quartzite	2	905	474.57	11	2,350	213.55
Other	6,240 r	74,700 r	11.98 r	8,990	93,800	10.43
Total or average	18,600 r	178,000 r	XX	21,000	194,000	XX
Calcium carbonate fines:[3]						
Natural chalk	(4)	11	95.47	(4)	21	87.87
Calcium carbonates, other chalk	1	275	325.06	1	496	597.59
Total or average	1	286	XX	1	517	XX
Grand total or average	18,600 r	179,000 r	XX	21,000	194,000	XX

rRevised. XX Not applicable.

[1]Data are rounded to no more than three significant digits, except unit value; may not add to totals shown.

[2]Cost, insurance, and freight value.

[3]Excludes precipitated calcium carbonate.

[4]Less than ½ unit.

Source: U.S. Census Bureau.

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STONE, DIMENSION

By Thomas P. Dolley

Domestic survey data and tables were prepared by Samir Hakim, statistical assistant.

U.S. production of dimension stone in 2005 was estimated to be 1.5 million metric tons (Mt) valued at $269 million, which was about a 4% decrease in value compared with that of 2004 (table 1). U.S. production tonnage of dimension stone in 2005 increased by about 3% compared with that of 2004. Exports increased in value by about 4% to $66.1 million, and imports for consumption increased by about 21% in value to about $2.18 billion. The value of apparent consumption was estimated to be $2.4 billion. Trade data in this report are from the U.S. Census Bureau. All percentages in the report were computed using unrounded data.

In recent years, most dimension stone has been used in construction applications with the largest portions being sold or used as ashlars and partially squared pieces, curbing, flagstone, and rough block for building and construction. Monumental stone, another major type, includes memorials of various kinds.

Dimension stone is a natural rock material quarried for the purpose of obtaining blocks or slabs that meet specifications as to size (width, length, and thickness) and shape. Color, grain texture and pattern, and surface finish of the stone also are normal requirements by both customers and the stone industry. Durability (essentially based on mineral composition, hardness, and past performance), strength, and the ability of the stone to take a polish are other important selection criteria.

Although various igneous, metamorphic, and sedimentary rocks are used as dimension stone, the principal rock types are granite, limestone, marble, sandstone, and slate. Other varieties of dimension stone that are normally considered to be special minor types include alabaster (massive gypsum) and soapstone (massive talc).

Description and Terminology

Scientific and commercial descriptions of various dimension stone types overlap. The scientific description of dimension stone types is focused primarily on the stone's geographic locality and mineralogical composition, whereas the commercial description is focused primarily on the locality and color of the stone. Furthermore, various combinations of the scientific and commercial descriptions are used by stone producers to market their stone products effectively. The descriptions that follow were adapted from Currier (1960, p. 1-10) and Barton (1968, p. 2-8).

Granite.—Commercial granites include all feldspathic crystalline rocks of mainly interlocking texture and with individual mineral grains that are visible to the naked eye. This category includes such rock types as anorthosite, gneiss, granite, granodiorite, monzonite, syenite, and all other intermediate igneous and coarse-grained metamorphic rock types. Primary colors of commercial granites are white, gray, pink, and red; green and brown are secondary colors. Although black granites are also included in this category and range in color from dark gray to black, they are not true granites mineralogically but rather mafic rocks, such as diabases, diorites, gabbros, and similar rocks.

Limestone.—Commercial limestones are rocks of sedimentary origin that primarily are composed of calcium carbonate with or without magnesium. Included in this category are limestone, dolomite, dolomitic limestone, and travertine, which is a calcitic rock that is precipitated from hot springs.

Marble.—Commercial marble includes metamorphosed limestones and serpentine rocks, all of which are capable of taking a polish. An important member of this classification is serpentine marble, which is also known as verde antique, and comprises green-to-black serpentine, which is a hydrous magnesium silicate mineral that is crisscrossed by veins of lighter minerals, such as calcite or dolomite.

Sandstone.—Commercial sandstone is a lithified sand that comprises chiefly of quartz or quartz and feldspar with a fragmental (clastic) texture. Sandstone contains interstitial cementing materials, such as calcite, clay, iron oxides, or silica. Arkose (abundant feldspar grains), graywacke (abundant angular rock fragments), and conglomerate (abundant rounded rock fragments) are included in this category. Other members of this category include bluestone, which is a dense, hard, fine-grained feldspathic sandstone that splits easily along planes into thin, smooth slabs; brownstone, which is feldspathic sandstone of brown to reddish-brown color owing to abundant iron oxide; and flagstone, which is a sandstone, or sandy slate, typically red, tan or gray, that splits into large, thin slabs.

Slate.—Commercial slate is a microgranular metamorphic rock formed by the recrystallization of clay sediments, such as claystone, shale, or siltstone. Characterized by excellent parallel cleavage, slates may be easily split into relatively thin slabs.

Greenstone.—Commercial greenstones are the result of the metamorphosis of basaltic rocks. Greenstone is named because of the predominance of greenish minerals, such as actinolite, chlorite, or epidote.

Basalt and Traprock.—Commercial basalt and traprock includes igneous rocks that are too fine grained to be termed "black granite." The name traprock is derived from the Swedish word "trappa," which means step, because of the characteristic terraced or steplike appearance of certain basalt lava fields. This category includes extrusive igneous rocks, such as andesite, basalt, or dacite, and intrusive igneous rocks, such as amphibolites, diabase, diorites, fine-grained gabbros, peridotites, and pyroxenites.

Miscellaneous.—This category includes commercial dimension stone types that do not easily fall into the aforementioned categories, such as soapstone, steatite, or talc, which contain various amounts of the mineral talc. Additional miscellaneous dimension stones include diatomite, mylonite, pumice, schist, tripoli, tuff, porous or scoriaceous volcanic rocks, or any other rocks used as building stones.

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Production

Dimension stone production data for the United States are derived by the U.S. Geological Survey (USGS) from a voluntary canvass of U.S. quarry producers of rough and dressed dimension stone. Of the 211 dimension-stone-producing operations included in the survey for 2005, 111 (53%) responded, which represented 69% of the tonnage; the remaining tonnage was estimated based partly on prior years' reporting (table 1). Data in this report cover rough crude quarried stone, irregular-shaped and rectangular blocks, and more highly processed stone. A number of other terms also are used to describe further processing, such as "worked," "dressed," "finished," and "manufactured." These and other terms used by the dimension stone industry describe such features as the mineral composition of the rock, the shape of the product, the method of finishing a stone, and the type of finish applied. No adjustments are made in the data to account for the sometimes substantial losses in processing rough stone into dressed stone. Sold or used data are considered to be equivalent to production because changes in stocks are not surveyed.

In 2005, limestone accounted for 581,000 metric tons (t) (38%) of the total domestic dimension stone production of 1.5 Mt, followed by granite (27%), marble (14%), sandstone (13%), miscellaneous stone (7%), and slate (1%). Granite accounted for about $106 million (39%) of the value of total domestic production of $269 million, followed by limestone (35%), sandstone (9%), marble (7%), miscellaneous (6%), and slate (4%).

Production was reported in 34 States and Puerto Rico. Leading producer States were, in descending order by tonnage, Wisconsin, Georgia, Indiana, Vermont, and Massachusetts. These States accounted for about 63% of the domestic production. The leading producer States were, in descending order by value, Indiana, Vermont, Wisconsin, Georgia, and South Dakota. These States contributed about 53% of the value of domestic production (table 3).

The top five producing companies were Buechel Stone Corp. in Wisconsin; Georgia Marble Co. (a subsidiary of Polycor Inc.) in Georgia; Victor Oolitic Stone Co. in Indiana; Rock of Ages Corp. in North Carolina, Pennsylvania, and Vermont; and Fletcher Granite Co., Inc. in Massachusetts, Maine, and New Hampshire. These companies produced about 45% of domestic production in tonnage and about 29% of production value. The leading 14 companies accounted for 67% of total domestically produced tonnage and 55% of the value.

Rough stone blocks split or cut from a quarry face are transported to processing plants that are typically located at the quarry site, at least for preliminary sizing. Further dressing, which includes final sizing and finishing operations, such as decorating, edging, and polishing, also may be done at the quarry site.

Granite.—Dimension granite was produced by 30 companies operating 56 quarries in 17 States. Production was 416,000 t valued at $106 million. Granite production tonnage decreased by 3% and the value decreased by 2% compared with those of 2004. The top five producing States were, in descending order by tonnage, Massachusetts, Vermont, Georgia, New Hampshire, and South Dakota. Massachusetts accounted for 19% of the tonnage of U.S. granite production. Massachusetts and Vermont combined accounted for about 23% of the value of the U.S. granite production (table 4).

Cold Spring Granite, Inc., Fletcher Granite, and Rock of Ages, which were the leading producers, accounted for 52% of U.S. granite production in tonnage and 23% of U.S. granite production in value.

Limestone.—Dimension limestone was produced by 28 companies from 31 quarries in 9 States. Production increased in 2005 by about 3% to 581,000 t from 564,000 t in 2004. The value increased slightly to $95.7 million in 2005 from $95 million in 2004. The top five producing States were, in descending order by tonnage Wisconsin, Indiana, Texas, Minnesota, and Kansas. Wisconsin and Indiana combined produced more than 86% of the U.S. tonnage and 74% of the value (table 5). Buechel Stone, Elliott Stone Co., Independent Limestone Co., Indiana Limestone, and Victor Oolitic Stone, which were the leading producers, accounted for 78% of all U.S. limestone tonnage and about 59% of the value.

Sandstone.—Dimension sandstone was produced by 24 companies that operated 27 quarries in 16 States. Production decreased by about 7% to 192,000 t in 2005 from 208,000 t in 2004. The value decreased slightly to $24.3 million in 2005 from $24.7 million in 2004. The top five producing States were, in descending order by tonnage, Arizona, New York, Ohio, Colorado, and Arkansas (table 6).

American Sandstone, Finger Lakes Stone Co. Inc., Hackett Quarry Co., Loukonen Brothers Stone Co., and Jude Stone Quarry Co., which were the leading producers, accounted for about 66% of the tonnage and 47% of the value of domestic production.

Marble.—Marble was mined by five companies that operated seven quarries in five States. Production more than doubled in 2005 to 207,000 t valued at $18.9 million from 98,700 t valued at $16.1 million in 2004 (table 10). Georgia was the leading producing State, followed by Vermont, Tennessee, Colorado, and Alabama. The leading producers were Georgia Marble, Vermont Quarries Co., and Tennessee Valley Marble. Additional data have been withheld to avoid disclosing company proprietary information.

Slate.—Slate was produced by 13 companies that operated 15 quarries in 5 States. Production decreased to 18,200 t in 2005 from 19,600 t in 2004. The value decreased to $11.2 million in 2005 from $13.7 million in 2004 (table 12). The top producing States were Vermont, Pennsylvania, and North Carolina. The leading producers were Pennsylvania Big Red Slate Co. Inc., Quarry Slate Industries Inc., and U.S. Quarried Slate Products Inc. Additional data have been withheld to avoid disclosing company proprietary information.

Consumption

Rough stone represented about 64% of the tonnage and 54% of the value of all dimension stone sold or used by domestic producers, which included exports. The leading uses of rough stone, by tonnage, were in other uses, which included flagging, exports, and unlisted and unspecified uses (36%), and in

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construction (34%). Dressed stone represented 36% by tonnage and 46% by value of the total stone sold or used. The leading uses within dressed stone, by tonnage, were in flagging (27%), curbing (24%), and ashlars and partially squared pieces (17%) (table 7).

Uses for the different varieties of dimension stone varied considerably. The major uses of granite sold or used in 2005, by tonnage, were in curbing (31%), monumental rough stone (22%), monumental dressed stone (14%), and rough blocks for building and construction (12%) (table 8). Primary uses of limestone, by tonnage, were in dressed stone other uses, including curbing, panels, veneer, tile, and unlisted and unspecified uses (56%), and rough blocks for building and construction (30%) (table 9). Primary uses of marble were, by tonnage, rough blocks for monumental and unspecified uses (62%), and rough blocks for building and construction (33%) (table 10). Primary uses of sandstone were, by tonnage, in dressed stone for flagging (63%) and rough blocks for building and construction (15%) (table 11). Dimension slate sold or used by producers in the United States in 2005, by tonnage, was principally for flooring (50%), roofing (18%), and flagging (14%) (table 12).

Overall, the value of apparent consumption of dimension stone in the United States was estimated to be $2.4 billion in 2005; this was an increase of about 20% compared with that of 2004. Apparent consumption is defined as production plus imports for consumption minus exports. Value data are used in the apparent consumption calculation because tonnage data are not available for imports and exports. Also, changes in industry stocks are not considered because such data are not available.

Prices

The average 2005 value for dimension stone was $178 per metric ton; this was a decrease of 7% from that of 2004 based on the USGS canvass. The average unit values for different types of dimension stone were granite, $254 per ton; limestone, $165 per ton; marble, $91 per ton; sandstone, $126 per ton; and slate, $617 per ton. Available price data show considerable variation. Prices are substantially different not only for the kind of stone, but also for the appearance of the same kind of stone. Color, grain structure, and finish contribute significantly to price and marketability.

Foreign Trade

Exports.—In 2005, total exports of dimension stone increased in value slightly to about $66.1 million compared with those of 2004; granite accounted for 58% of the export value. The largest share of granite was exported to China (table 13). Although unreported, a significant amount of granite was probably reexported back to the U.S. market.

Imports.—The value of imports for consumption of dimension stone types increased in 2005 by 22% to $2.2 billion. Brazil superseded Italy as the major single source of imported granite in 2005, accounting for 31% by value. Italy, which continued to be a major source of granite, accounted for 25% of granite imports by value. Other important granite import sources included China (17%) and India (15%) (table 14). Italy also was a major source of rough and dressed marble imports (tables 15, 16). Duties on imported dimension stone are listed in table 2.

World Industry Structure

World dimension stone production, including the United States, was estimated to be approximately 93 Mt in 2005. Although there was probably some small-scale production in the majority of the world's nations, dimension stone was produced and officially reported in about 26 countries. The top five producing countries in 2005 were, in descending order by tonnage, China, India, Iran, Italy, and Spain, and these countries accounted for about 68% of the world's production. The United States ranked 11th in world production of dimension stone in 2005 (Internazionale Marmi e Macchine Carrara S.p.A., 2006§[1]).

Outlook

Dimension stone sales during the near term are expected to remain level. For residential and office building construction, growth in the use of dimension stone is expected in new home construction, new prestige markets for home improvement, as well as in renovations to attract and keep tenants. Conversely, some sectors of the stone industry report a lack of skilled labor at quarries and that, in recent years, competent masons have left the stone industry for more lucrative and higher paying building projects in the construction industry.

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TABLE 1
SALIENT U.S. DIMENSION STONE STATISTICS[1]

(Thousand metric tons and thousand dollars)

	2001	2002	2003	2004	2005
Sold or used by producers:[2]					
Quantity	1,220	1,260	1,340	1,460	1,500
Value	263,000	254,000	268,000	281,000	269,000
Exports, value	73,500	64,400	63,500	63,700	66,100
Imports for consumption, value	1,070,000	1,190,000	1,390,000	1,790,000	2,180,000

[1]Data are rounded to no more than three significant digits.
[2]Includes Puerto Rico and other U.S. possessions and territories.

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TABLE 2
U.S. IMPORT DUTIES ON DIMENSION STONE

Tariff item	HTS[1] code	NTR,[2] January 1, 2005	Non-NTR,[2] January 1, 2005
Slate, rough blocks or slabs	2514.00.0000	Free	25% ad valorem.
Rough blocks or slabs of marble, travertine, other calcareous monumental or building stone:	2515.00.0000		
Marble and travertine:			
Crude or roughly trimmed	2515.11.0000	Free	$22.95 per cubic meter.
Marble, merely cut	2515.12.1000	do.	13% ad valorem.
Travertine, merely cut	2515.12.2000	3.0% ad valorem	50% ad valorem.
Other calcareous stone alabaster	2515.20.0000	do.	Do.
Rough blocks or slabs of granite, porphyry, basalt, sandstone, other monumental or building stone:	2516.00.0000		
Granite:			
Crude or roughly trimmed	2516.11.0000	Free	$8.83 per cubic meter.
Merely cut	2516.12.0000	2.8% ad valorem	60% ad valorem.
Sandstone:			
Crude or roughly trimmed	2516.21.0000	Free	$5.30 per cubic meter.
Merely cut	2516.22.0000	3.0% ad valorem	50% ad valorem.
Other monumental or building stone	2516.90.0000	do.	Do.
Setts, curbstones, flagstones	6801.00.0000	2.8% ad valorem	60% ad valorem.
Worked monumental or building stone:	6802.00.0000		
Tiles and cubes under 7 centimeters square, granules	6802.10.0000	4.8% ad valorem	40% ad valorem.
Other stone and articles with a flat or even surface:			
Marble, travertine, and alabaster:	6802.21.0000		
Travertine	6802.21.1000	4.2% ad valorem	50% ad valorem.
Other	6802.21.5000	1.9% ad valorem	13% ad valorem.
Other calcareous stone	6802.22.0000	4.9% ad valorem	50% ad valorem.
Granite	6802.23.0000	3.7% ad valorem	60% ad valorem.
Other stone	6802.29.0000	6.0% ad valorem	30% ad valorem.
Other:			
Marble, travertine, and alabaster:	6802.91.0000		
Marble:			
Slabs	6802.91.0500	2.5% ad valorem	15% ad valorem.
Other	6802.91.1500	4.9% ad valorem	50% ad valorem.
Travertine:			
Travertine articles of subheading 6802.21.1000 that have been dressed or polished, but not further worked	6802.91.2000	4.2% ad valorem	50% ad valorem.
Other	6802.91.2500	3.7% ad valorem	40% ad valorem.
Alabaster	6802.91.3000	4.7% ad valorem	50% ad valorem.
Other calcareous stone	6802.92.0000	4.9% ad valorem	Do.
Granite	6802.93.0000	3.7% ad valorem	60% ad valorem.
Other stone	6802.99.0000	6.5% ad valorem	40% ad valorem.
Worked slate and articles:	6803.00.0000		
Roofing slate	6803.00.1000	3.3% ad valorem	25% ad valorem.
Other	6803.00.5000	Free	Do.

[1]Harmonized Tariff Schedule of the United States.
[2]Normal trade relations.

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TABLE 3
DIMENSION STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

State	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
California	42,100	$10,200	41,000	$10,200
Colorado	16,200	1,980	18,200	2,400
Georgia	146,000	22,100	246,000	21,000
Indiana	251,000	45,500	240,000	46,300
Kansas	13,900	1,730	13,100	1,590
Maryland	26,700	9,580	25,700	3,010
Massachusetts	81,700	11,600	81,800	11,500
Minnesota	21,600	12,400	18,600	13,400
Montana	13,900	2,550	11,600	2,620
New Mexico	57,000	2,430	6,660	279
New York	43,600	4,560	42,100	7,470
North Carolina	43,000	18,200	39,500	17,000
Ohio	37,700	5,100	28,200	4,880
Oklahoma	16,500	2,100	3,200	501
Pennsylvania	32,600	10,100	35,400	11,800
South Carolina	9,230	850	9,230	850
Texas	63,600	15,200	44,000	12,200
Vermont	100,000	30,600	98,000	27,800
Virginia	5,410	594	5,640	631
Wisconsin	232,000	23,800	278,000	27,600
Other[2]	206,000	49,600	219,000	45,500
Total	1,460,000	281,000	1,500,000	269,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes Alabama, Arizona, Arkansas, Connecticut, Idaho, Maine, Michigan, Missouri, New Hampshire, South Dakota, Tennessee, Utah, Washington, West Virginia, Puerto Rico, and other U.S. possessions and territories.

TABLE 4
DIMENSION GRANITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

State	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
California	17,200	$5,800	17,300	$5,810
Georgia	75,400	9,630	64,300	8,590
Massachusetts	81,700	11,600	81,800	11,500
South Carolina	9,230	850	9,230	850
Wisconsin	12,100	2,200	2,550	1,690
Other[2]	233,000	77,800	241,000	77,300
Total	429,000	108,000	416,000	106,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes Maine, Minnesota, Missouri, New Hampshire, New York, Oklahoma, North Carolina, Pennsylvania, South Dakota, Texas, Vermont, Virginia, Puerto Rico, and other U.S. possessions and territories.

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TABLE 5
DIMENSION LIMESTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

State	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Indiana	249,000	$45,400	240,000	$46,300
Kansas	12,200	1,570	11,700	1,490
Other[2]	303,000	48,000	329,000	47,900
Total	564,000	95,000	581,000	95,700

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes Arkansas, California, Minnesota, Ohio, Oklahoma, Texas, and Wisconsin.

TABLE 6
DIMENSION SANDSTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY STATE[1]

State	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
New York	41,300	$3,170	39,700	$6,080
Pennsylvania	2,330	357	2,350	358
Other[2]	164,000	21,100	150,000	17,900
Total	208,000	24,700	192,000	24,300

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes Arizona, Arkansas, California, Colorado, Idaho, Kansas, Michigan, New Mexico, Ohio, Oklahoma, Utah, Virginia, West Virginia, and Wisconsin.

TABLE 7
DIMENSION STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE[1, 2]

Use	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Rough stone:				
Rough blocks for building and construction	414,000	$68,700	324,000	$43,000
Irregular-shaped stone	77,100	10,100	72,900	9,850
Monumental	138,000	14,100	221,000	27,700
Other[3]	257,000	32,700	347,000	66,000
Dressed stone:				
Ashlars and partially squared pieces	104,000	17,500	91,100	20,600
Slabs and blocks for building and construction	15,900	6,900	14,400	3,670
Monumental	63,100	30,700	59,500	27,500
Curbing	130,000	21,500	129,000	20,600
Flagging	170,000	20,800	146,000	13,700
Flagging (slate)	1,240	245	2,550	837
Roofing slate	4,860	8,060	3,310	5,130
Structural and sanitary	2,370	2,710	2,270	2,590
Flooring slate	8,870	1,720	9,030	1,920
Other[4]	75,500	45,000	82,400	25,700
Grand total	1,460,000	281,000	1,500,000	269,000

[1]Includes Puerto Rico and other U.S. possessions and territories.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Includes flagging stone, exports, uses not specified, and uses not listed.

[4]Includes panels and veneer, tile, blackboards, exports, uses not specified, and uses not listed.

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TABLE 8

DIMENSION GRANITE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE[1]

Use	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Rough stone:				
Rough blocks for building and construction	103,000	$29,200	48,800	$8,700
Irregular-shaped stone	9,870	1,140	10,900	1,430
Monumental	59,900	6,810	90,900	18,500
Other[2]	39,300	11,700	48,200	17,000
Dressed stone:				
Ashlars and partially squared pieces	3,690	1,550	5,260	2,140
Slabs and blocks for building and construction	1,640	808	731	595
Monumental	61,600	28,200	59,400	27,400
Curbing	129,000	21,400	129,000	20,500
Other[3]	20,900	7,070	22,900	9,350
Grand total	429,000	108,000	416,000	106,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes exports and uses not listed.

[3]Includes panels and veneer, tile, uses not specified, and uses not listed.

TABLE 9

DIMENSION LIMESTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE[1]

Use	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Rough stone:				
Rough blocks for building and construction	201,000	$29,400	172,000	$24,600
Irregular-shaped stone	13,500	1,290	11,500	1,000
Monumental	16,100	4,400	772	92
Other[2]	4,080	574	4,730	624
Dressed stone:				
Ashlars and partially squared pieces	65,800	10,700	52,300	12,000
Slabs and blocks for building and construction	11,500	2,290	8,270	1,980
Flagging	11,300	4,130	4,140	1,270
Other[3]	241,000	42,300	327,000	54,100
Grand total	564,000	95,000	581,000	95,700

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes exports and uses not listed.

[3]Includes curbing limestone, panels and veneer, tile, uses not specified, and uses not listed.

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TABLE 10

DIMENSION MARBLE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE[1, 2]

Use	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Rough stone:				
Rough blocks for building and construction	85,100	$6,880	69,400	$6,910
Other[3]	5,170	837	129,000	9,040
Dressed stone:				
Slabs and blocks for building and construction	W	W	W	W
Monumental	W	W	W	W
Flagging	W	W	W	W
Tile	W	W	W	W
Other[4]	8,380	8,350	8,780	2,960
Grand total	98,700	16,100	207,000	18,900

W Withheld to avoid disclosing company proprietary data; included with "Dressed stone, other."

[1]Includes Puerto Rico.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Includes monumental stone, uses not specified, and uses not listed.

[4]Includes slabs and blocks, flagging, monumental, panels and veneer, ashlars and partially squared pieces, tile, uses not listed, and uses indicated by symbol W.

TABLE 11

DIMENSION SANDSTONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE[1]

Use	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Rough stone:				
Rough blocks for building and construction	41,000	$2,990	29,400	$2,350
Irregular-shaped stone	12,800	2,060	16,300	2,780
Other[2]	--	--	2,270	2,000
Dressed stone:				
Ashlars and partially squared pieces	14,500	2,960	15,500	2,950
Slabs and blocks for building and construction	2,490	746	2,490	746
Curbing	W	W	W	W
Flagging	132,000	13,300	121,000	9,750
Panels and veneer	907	300	1,360	340
Other[3]	4,160	2,260	3,910	3,400
Grand total	208,000	24,700	192,000	24,300

W Withheld to avoid disclosing company proprietary data; included with "Dressed stone, other." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes flagging stone and uses not listed.

[3]Includes tile, curbing, exports, uses not specified, uses not listed, and uses indicated by symbol W.

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TABLE 12

DIMENSION SLATE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, BY USE[1]

Use	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Flagging	2,400	$436	2,550	$837
Roofing	4,860	8,060	3,310	5,130
Structural and sanitary purposes	2,370	2,710	2,270	2,590
Flooring	8,870	1,720	9,030	1,920
Other[2]	1,080	774	1,040	762
Total	19,600	13,700	18,200	11,200

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes uses not specified and uses not listed.

TABLE 13

U.S. EXPORTS OF DIMENSION STONE, BY TYPE[1]

(Thousand metric tons and thousand dollars)

Type	2004 Quantity	2004 Value	2005 Quantity	2005 Value	Major destination in 2005[2]
Marble, travertine, alabaster worked[3]	39	3,330	42	4,320	Canada, 56%.
Marble, travertine, crude or roughly trimmed	3	1,630	3	1,040	Canada, 80%.
Marble, travertine, merely cut, by sawing or otherwise[4]	3	1,400	5	1,700	Japan, 18%.
Granite, crude or roughly trimmed	131	36,900	123	33,000	China, 42%.
Granite, merely cut by sawing or otherwise[4]	12	4,010	12	5,010	Mexico, 15%.
Sandstone, crude or roughly trimmed	5	1,140	5	1,580	Canada, 77%.
Sandstone, merely cut, by sawing or otherwise[4]	6	1,580	5	1,680	Canada, 91%.
Slate, worked and articles of slate	NA	5,760	NA	4,150	Canada, 44%.
Slate, whether or not roughly trimmed or merely cut[4]	NA	454	NA	733	Canada, 79%.
Other calcareous monumental or building stone; alabaster[5]	18	4,970	36	8,730	Canada, 95%.
Other monumental or building stone[6]	15	2,490	33	4,130	Canada, 87%.
Total	XX	63,700	XX	66,100	

NA Not available. XX Not applicable.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]By value.

[3]Further worked than simply cut with a flat surface.

[4]Blocks or slabs.

[5]Crude, roughly trimmed, or merely cut into blocks or slabs. Other than marble and travertine (includes alabaster).

[6]Crude, roughly trimmed, or merely cut into blocks or slabs. Other than calcareous stone and alabaster, granite, sandstone, slate, dolomite, quartzite, and steatite.

Source: U.S. Census Bureau.

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TABLE 14

U.S. IMPORTS FOR CONSUMPTION OF DIMENSION GRANITE, BY COUNTRY[1]

(Thousand dollars)

Country	Rough granite[3]	Dressed								
		Simply cut[4]	Worked granite						Total worked	Total dressed
			Not cut to size[5]	Cut to size[2]						
				Maximum 1.5 centimeters	1.5-7.5 centimeters	Monumental minimum 7.5 centimeters	Building minimum 7.5 centimeters	Other		
2004:										
Argentina	55	159	228	119	1,900	--	76	157	2,480	2,640
Brazil	10,900	27,900	50,800	6,790	143,000	227	4,150	28,200	234,000	261,000
Canada	4,170	1,180	187	3,150	15,400	7,250	10,300	11,100	47,400	48,600
China	4,660	11,700	10,400	16,700	54,800	6,090	8,650	32,300	129,000	141,000
Finland	8	7	--	6	68	--	2	11	87	94
India	7,740	14,700	15,100	10,900	81,000	7,530	6,140	23,300	144,000	159,000
Italy	7,600	21,100	37,900	7,820	152,000	924	10,300	51,700	261,000	282,000
Japan	--	32	--	--	--	--	--	593	593	625
Mexico	407	1,550	26	19	404	--	136	632	1,220	2,760
Norway	351	14	--	--	126	--	5	21	152	166
Portugal	68	342	65	86	222	--	19	246	638	980
Saudi Arabia	255	33	46	67	1,510	--	35	123	1,780	1,810
South Africa	2,670	210	341	32	3,190	9	60	476	4,110	4,320
Spain	814	2,700	3,690	1,300	18,300	37	429	4,330	20,600	23,300
Other	1,120	2,160	17,800	854	23,500	16	2,570	9,350	54,100	56,300
Total	40,800	83,600	137,000	47,800	496,000	22,100	42,900	163,000	900,000	984,000
2005:										
Argentina	--	269	219	21	1,700	--	45	285	2,270	2,540
Brazil	12,800	54,700	67,400	6,920	215,000	291	5,910	36,200	331,000	386,000
Canada	3,960	1,040	663	4,160	14,400	7,430	8,700	6,920	42,200	43,300
China	5,520	24,900	20,700	21,100	86,300	7,000	10,000	47,600	193,000	218,000
Finland	--	8	33	--	69	--	6	392	500	508
India	7,170	31,900	21,000	11,200	86,300	7,350	6,500	24,100	156,000	188,000
Italy	6,050	29,500	42,900	4,920	154,000	313	7,260	53,700	263,000	311,000
Japan	3	147	--	--	--	--	--	--	--	147
Mexico	431	1,470	185	68	62	--	2	275	592	2,060
Norway	199	25	--	--	111	--	--	49	160	185
Portugal	8	54	54	3	269	--	60	123	509	563
Saudi Arabia	337	163	123	49	2,620	--	27	39	2,860	3,020
South Africa	2,040	10	514	3	4,230	--	29	265	5,040	5,050
Spain	515	3,910	3,130	840	16,800	--	182	3,680	24,600	28,500
Other	2,110	4,870	21,100	770	19,400	233	1,700	6,310	49,500	54,400
Total	41,200	153,000	178,000	50,100	601,000	22,600	40,500	180,000	1,070,000	1,240,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]One or more faces worked more than simply cut.

[3]Normal quarry products. Includes crude or roughly trimmed and roughly cut by sawing or otherwise; Harmonized Tariff Schedule of the United States (HTS) codes 2516.11.0000, 2516.12.0030, and 2516.12.0060.

[4]Simply cut with a flat even surface; HTS code 6802.23.0000.

[5]Only one face worked more than simply cut; HTS code 6802.93.0010.

Source: U.S. Census Bureau.

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TABLE 15

U.S. IMPORTS FOR CONSUMPTION OF MAJOR CATEGORIES OF DIMENSION MARBLE AND OTHER CALCAREOUS STONE, BY COUNTRY[1]

	Dressed							
	Marble, slabs[2]		Marble, other[3]		Other calcareous stone[4]		Rough marble[5]	
Country	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
2004:								
Brazil	3,810	$3,420	491	$376	2,880	$1,470	92	$73
Canada	112	184	1,040	1,980	4,420	3,610	10	23
China	18,600	8,690	40,900	29,600	48,500	21,100	792	546
France	389	783	252	1,140	63,800	17,400	10	27
Greece	4,680	6,600	7,010	8,540	2,400	2,780	6	19
India	2,990	2,430	4,280	6,130	5,600	3,350	48	38
Israel	2,240	2,000	6,240	6,040	12,100	13,000	332	275
Italy	58,300	74,300	59,600	75,900	76,600	55,100	948	1,280
Mexico	2,040	1,360	10,900	11,700	10,500	9,210	132	138
Portugal	2,350	2,410	2,450	2,320	11,700	8,700	39	20
Spain	23,300	18,700	30,300	27,900	94,700	57,900	1,090	947
Taiwan	658	697	2,290	3,550	517	504	41	54
Turkey	8,010	6,240	35,400	25,600	25,900	11,600	425	314
Other[r]	8,650	7,290	21,700	17,800	69,100	23,800	1,070	838
Total	136,000	135,000	223,000	219,000	429,000	230,000	5,030	4,590
2005:								
Brazil	3,580	3,130	573	455	3,600	1,490	398	216
Canada	77	225	427	933	323,000	5,270	15	24
China	31,200	16,400	41,900	35,900	31,900	20,100	1,260	829
France	672	1,630	846	1,420	59,200	15,700	18	30
Greece	5,390	7,710	7,200	10,500	1,370	1,520	8	8
India	4,600	3,880	4,640	5,830	3,690	2,090	105	87
Israel	2,450	2,100	6,630	6,620	20,100	16,700	40	61
Italy	71,100	92,200	54,400	79,900	35,000	39,900	2,510	2,950
Mexico	3,160	2,940	12,200	13,400	28,500	11,100	124	179
Portugal	4,860	3,980	2,990	2,780	13,100	10,700	16	22
Spain	33,900	31,100	39,600	37,700	48,900	42,100	871	984
Taiwan	1,120	1,070	1,810	3,010	1,190	361	35	42
Turkey	12,600	9,710	50,500	35,000	15,100	13,000	2,520	1,120
Other	12,200	10,100	30,000	24,800	59,200	25,900	1,270	905
Total	187,000	186,000	254,000	258,000	644,000	206,000	9,190	7,450

[r]Revised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Worked more than simply cut with a flat surface; Harmonized Tariff Schedule of the United States (HTS) code 6802.91.0500.

[3]Merely cut by sawing or otherwise.

[4]Worked more than simply cut with a flat surface, other than marble and travertine; HTS code 6802.92.0000.

[5]Simply cut by sawing or otherwise into rectangular blocks or slabs; HTS code 2515.12.1000.

Source: U.S. Census Bureau as modified by the U.S. Geological Survey.

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TABLE 16

U.S. IMPORTS FOR CONSUMPTION OF DIMENSION STONE, BY TYPE[1]

Type		2004 Quantity	2004 Value (thousands)	2005 Quantity	2005 Value (thousands)	Major source for 2005[2]
Calcareous stone, other[3]	metric tons	10,300	$7,130	34,700	$8,280	Italy, 22%.
Marble and alabaster[4]	do.	19,200	15,000	29,200	23,500	Italy, 26%.
Sandstone, cut, by sawing or otherwise[5]	do.	1,290	798	4,420	2,180	India, 61%.
Slate, roofing	million square feet	15	7,000	13	7,970	China, 32%.
Slate, roughly trimmed or simply cut[5]	do.	14,100	4,880	18,300	6,000	China, 38%.
Slate, worked and articles of slate, and other[6]	do.	NA	91,300	NA	113,000	India, 40%.
Travertine, monumental or building stone and articles thereof[7]	do.	41,700	27,200	67,000	41,400	Turkey, 65%.
Travertine, worked monumental or building stone[8]	do.	114,000	61,700	118,000	62,800	Turkey, 58%.
Other stone, monumental or building stone[9]	do.	17,500	8,010	20,500	11,100	Mexico, 21%.

NA Not available.

[1]Data are rounded to no more than three significant digits. Table does not include totals shown on tables 14 and 15.

[2]By value.

[3]Simply cut with a flat surface, other than marble, travertine, and alabaster.

[4]Simply cut with a flat surface.

[5]Rectangular blocks or slabs.

[6]Other than roofing, including agglomerated slate.

[7]Simply cut with a flat surface, other than tiles and granules.

[8]Dressed or polished but not further worked.

[9]Simply cut with a flat surface, other than granite, calcareous stone, alabaster, slate, dolomite, quartzite, and steatite.

Source: U.S. Census Bureau.

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STRONTIUM

By Joyce A. Ober

Domestic survey data and tables were prepared by Hoa P. Phamdang, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Domestic strontium consumption decreased for the sixth consecutive year because its major end use, color television faceplate glass production, had declined dramatically in the United States owing to the shift of production to Asia and increased popularity of new flat panel television displays that do not use strontium carbonate in their glass. Worldwide, strontium ore production increased as a result of significantly expanded production in China and Mexico.

Strontium occurs commonly in nature; it averages 0.04% of the Earth's crust and is the 15th element in abundance (MacMillan and others, 1994). Only two minerals, celestite (strontium sulfate) and strontianite (strontium carbonate), however, contain strontium in sufficient quantities to make its recovery practical. Of the two, celestite occurs much more frequently in sedimentary deposits of sufficient size to make development of mining facilities attractive. Neither mineral is mined in the United States, although deposits have been identified and were mined in the past.

Legislation and Government Programs

In 2005, the National Defense Stockpile contained approximately 12,000 metric tons (t) of celestite, which was authorized by the U.S. Congress for disposal. No bids were made on the material that was offered for sale. Celestite has been offered for sale from the stockpile every year since 1994; none has been sold. The low quality of the material that remains in the stockpile makes it undesirable as raw material for strontium carbonate production. Reports issued by the Defense National Stockpile Center of the Defense Logistics Agency, the agency responsible for managing stockpile sales, list the celestite as valueless.

Production

Chemical Products Corp. (CPC) of Cartersville, GA, voluntarily provided domestic production and sales data to the U.S. Geological Survey (USGS). These data, however, have been withheld from publication to avoid disclosing company proprietary data (table 1). CPC, the only domestic company that produced large quantities of strontium chemicals and the sole U.S. producer of strontium compounds from celestite, has been a long-term consumer of celestite from Mexico; CPC also owned and operated a strontium carbonate plant in Reynosa, Mexico.

Late in 2005, CPC finalized an agreement with Solvay S.A. of Belgium, the world's leading producer of strontium compounds, to form a joint venture. The new company, named Solvay & CPC Barium Strontium GmbH & Co. KG, will manage CPC's and Solvay's technical-grade barium and strontium carbonate, sodium sulfide, sodium hydrosulfide, and strontium nitrate businesses. Aligning the two companies' operations in Germany, India, the Republic of Korea, and Mexico allowed them to compete more efficiently in the changing markets, especially in Asia (Solvay S.A., 2005).

Consumption

The USGS estimated the distribution of strontium compounds by end use. Of the six operations to which a survey request was sent, five responded. The information collected from this survey and the information provided by the U.S. Census Bureau on strontium trade were the bases for the end-use estimates listed in table 2.

In 2005, almost 70% of all strontium was consumed in ceramics and glass manufacture, primarily in television faceplate glass and secondarily in ceramic ferrite magnets and other ceramic and glass applications. Although consumption in television glass declined, it remained the predominant end use for strontium.

All color televisions and other devices that contain color cathode-ray tubes (CRTs) sold in the United States are required by law to contain strontium in the faceplate glass of the picture tube to block x-ray emissions. Major manufacturers of television picture tube glass incorporate, by weight, about 8% strontium oxide in their glass faceplate material. Added to the glass melt in the form of strontium carbonate, strontium is converted to strontium oxide. In addition to blocking x rays, strontium improves the appearance of the glass and the quality of the picture and increases the brilliance (Wagner, 1986). Domestic television glass production began a steep decline with the closure of one plant in 2003 and the closure of three in 2004. At the end of 2005, only one plant in Pennsylvania produced television glass.

Permanent ceramic magnets are another end use for strontium compounds in the form of strontium ferrite. These magnets are used extensively in small direct current motors for automobile windshield wipers, loudspeakers, magnetically attached decorative items, toys, and other electronic equipment. Strontium ferrite magnets have high coercive force and high thermal and electrical resistivities and are chemically inert. They retain their magnetism well, are not adversely affected by electrical currents or high temperatures, do not react with most chemical solvents, and have a low density (Haberberger, 1971).

One of the most consistent and continuing applications for strontium is in pyrotechnic devices. Strontium burns with a brilliant red flame, and no other material is known to perform better in this application. The compound used most frequently in these devices is strontium nitrate, although strontium carbonate, strontium chlorate, strontium oxalate, and strontium sulfate

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may also be used. Pyrotechnic devices are used in military and nonmilitary applications. Military pyrotechnic applications include marine distress signals, military flares, and tracer ammunition. Nonmilitary applications include fireworks and warning devices (Conkling, 1981).

Strontium can be used to remove lead impurities during the electrolytic production of zinc. The addition of strontium carbonate dissolved in sulfuric acid reduces the lead content of the electrolyte and of the zinc deposited on the cathode (Bratt and Smith, 1963).

Strontium chromate is used as an additive in corrosion-resistant paint to effectively coat aluminum, most notably on aircraft fuselages and ships. These paints are used, to some degree, on aluminum packaging to prevent corrosion (Roskill Information Services Ltd., 1992, p. 76).

Strontium metal was a very small part of total strontium consumption. Small amounts of strontium added to molten aluminum make it more suitable for casting such items as engine blocks and wheels. The addition of strontium to the melt also improves the machinability of the casting. The use of cast aluminum parts instead of steel has become common in the automotive industry because of the reduced weight and resulting improved gas mileage (Lidman, 1984).

Other end uses consumed only small amounts of strontium and strontium compounds. Strontium improves the quality of certain ceramic glazes and eliminates the toxicity that may be present in glazes that contain barium or lead. Strontium titanate is sometimes used as a substrate material for semiconductors and in some optical and piezoelectric applications. Strontium chloride is used in toothpaste for temperature-sensitive teeth. For this application, impurities must be strictly controlled; some limits are in the parts-per-million range. Strontium phosphate is used in the manufacture of fluorescent lights, and the entire range of strontium chemicals is used in analytical chemistry laboratories.

Prices

According to data published by the U.S. Census Bureau, the average customs value for celestite imported from Mexico was about $56 per metric ton, which was 5.7% higher than that of 2004. The average unit customs value of imported strontium carbonate was $0.39 per kilogram, which was an increase of 8.4% from $0.36 per kilogram in 2004. In 2005, the unit value of imported strontium metal decreased 42% in 2005 to $2.87 per kilogram from $4.94 per kilogram. In 2005, the corresponding value for strontium nitrate was $0.89 per kilogram, which was a 41% decrease from $1.52 per kilogram in 2004.

Foreign Trade

Exports of strontium chemicals were less than one-half what they were in 2004 (tables 1, 3). Imports of celestite from Mexico were 1,820 t, which was only 29% of the amount imported the previous year (table 4). Based on these data, it can be assumed that strontium carbonate production in the United States has decreased dramatically in recent years.

In 2005, Mexico continued to be the most important source for imported strontium chemicals with almost 82% of the total, followed by Germany with 7%, although total imports declined compared with the previous year. Imports of strontium carbonate were 24% lower than those of 2004. Imports from Mexico accounted for 87% of total strontium carbonate imports. Imports of strontium metal were significantly higher in 2005, reaching 770,000 kilograms, more than three times what they were the previous year. Virtually all of the reported strontium metal imports were from Japan (63%), China (24%), and the Republic of Korea (13%). Imports of strontium nitrate, which until 2005 was the second ranked imported strontium compound, vary significantly from year to year but typically represent about 2% to 4% of total strontium imports. In 2005, imports of strontium nitrate were 36% higher than those of 2004.

World Review

In most instances, celestite deposits occur in remote, undeveloped locations far from population centers and in areas where inexpensive labor is available for mining. Huge deposits of high-grade celestite have been discovered throughout the world. Strontium commonly occurs along with barium and calcium, which have chemical properties very similar to strontium, thus making separation difficult. Because removing many impurities from celestite is difficult and energy-intensive, strontium chemical producers require that raw materials contain at least 90% strontium sulfate. Most operating celestite facilities produce sufficient supplies with only minimal processing necessary to achieve acceptable specifications. Hand sorting and some washing are all that are necessary at many strontium mines; a few operations use froth flotation, gravity separation, or other methods to beneficiate ore.

The leading celestite producing countries were, in decreasing order of output, Spain, China, and Mexico, all with more than 100,000 t of production in 2005. Turkey was another leading celestite producer. Significant quantities of celestite were believed to have been produced in Tajikistan, but not enough information was available to make an estimate on the level of production. Celestite was produced in smaller quantities in Argentina, Iran, Morocco, and Pakistan (table 5). Production facilities for strontium compounds and metal were located in Canada, China, Germany, Japan, the Republic of Korea, Mexico, and the United States.

Detailed information on most world resources was not readily available because very little information on exploration results has been published. Other deposits may be well identified but are in countries from which specific minerals information was not easily obtained.

Outlook

Major production of faceplate glass for CRT televisions and computer monitors has shifted to the Far East, especially China, where increasing numbers of these devices are being produced and purchased. For that reason, strontium consumption has shifted to that region also. In developed countries, flat panel display technology that requires little or no strontium continues to gain market share as the market prices decrease as a result of increased production capacity. Market economics have shifted

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the production of faceplate glass and smaller televisions to Asia and Mexico where they now are being built for sale in the United States. These changes have resulted in plummeting domestic strontium carbonate production with little likelihood of recovery in the future. Television glass production also has declined in Europe and Japan. Strontium demand for CRTs continues to be strong in Asia and Mexico, but newer television technology could possibly replace CRTs in those markets as well.

Ferrite magnet markets are expected to be strong, and demand for strontium is likely to continue. Growth in other markets will probably continue at the current slower rate. Improved economic conditions worldwide could spur growth in demand for strontium carbonate applications.

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TABLE 1
SALIENT STRONTIUM STATISTICS[1]

(Metric tons of contained strontium and dollars per metric ton unless otherwise noted)[2]

	2001	2002	2003	2004	2005
United States:					
Production, strontium minerals	--	--	--	--	--
Imports for consumption:[3]					
Strontium compounds	26,500	25,400	23,300	14,500	11,700
Strontium minerals	5,640	1,150	1,020	2,760	799
Exports, compounds[3]	929	340	693	552	255
Shipments from Government stockpile excesses	--	--	--	--	--
Apparent consumption[4]	31,200	26,200	23,600	16,700	12,200
Price, average value of mineral imports at port of exportation	63	60	57	53	56
World, production of celestite, gross weight[e, 5]	399,000 r	435,000	471,000 r	457,000 r	494,000

[e]Estimated. [r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits.

[2]The strontium content of celestite is 43.88%, which was used to convert units to celestite.

[3]Source: U.S. Census Bureau.

[4]Production plus imports minus exports.

[5]Excludes Tajikistan, which was believed to produce significant quantities of celestite, but information was not available to make reliable estimates.

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TABLE 2
U.S. ESTIMATED DISTRIBUTION OF PRIMARY
STRONTIUM COMPOUNDS, BY END USE

(Percent)

End use	2004	2005
Electrolytic production of zinc	2	2
Ferrite ceramic magnets	11	13
Pigments and fillers	2	3
Pyrotechnics and signals	14	22
Television picture tubes	68	55
Other	3	5
Total	100	100

TABLE 3
U.S. EXPORTS OF STRONTIUM COMPOUNDS, BY COUNTRY[1]

	2004		2005	
	Gross weight (kilograms)	Value[2]	Gross weight (kilograms)	Value[2]
Strontium carbonate, precipitated:				
Canada	36,900	$27,600	--	--
China	--	--	18,600	$17,700
Germany	9,930	40,200	14,000	126,000
Hong Kong	45,600	43,400	15,400	14,600
Japan	55,400	31,100	5,200	5,970
Korea, Republic of	5,000	4,750	--	--
Malaysia	80,000	32,000	--	--
Mexico	108,000	46,600	5,370	5,100
Singapore	4,190	3,980	--	--
United Kingdom	14,700	36,100	2,010	9,240
Venezuela	--	--	3,990	16,900
Total	360,000	266,000	64,500	196,000
Strontium oxide, hydroxide, peroxide:				
Australia	27,200	14,900	--	--
Belgium	57,600	37,500	103,000	62,700
Brazil	12,600	6,930	--	--
Canada	67,200	34,400	44,100	17,200
China	--	--	7,580	4,170
Denmark	--	--	32,200	17,700
France	--	--	26,200	14,400
Japan	56,200	220,000	18,600	10,200
India	--	--	1,020	5,800
Israel	12,500	6,860	--	--
Korea, Republic of	146,000	80,400	41,100	22,600
Mexico	28,400	43,000	2,000	6,820
Thailand	10,800	5,940	--	--
Sweden	4,690	2,580	25,300	13,900
Switzerland	16,200	8,920	--	--
United Kingdom	29,400	16,200	--	--
Total	469,000	477,000	301,000	176,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship value.

Source: U.S. Census Bureau.

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TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF STRONTIUM COMPOUNDS, BY COUNTRY[1]

	2004		2005	
	Gross weight (kilograms)	Value[2]	Gross weight (kilograms)	Value[2]
Celestite, Mexico	6,290,000	$332,000	1,820,000	$98,400
Strontium carbonate:				
Belgium	161,000	63,800	279,000	117,000
China	77,000	30,000	46,000	47,700
Germany	1,680,000	723,000	1,340,000	661,000
Italy	2,000	8,720	5,000	20,700
Japan	--	--	4,630	70,600
Mexico	21,700,000	7,580,000	15,600,000	5,620,000
Spain	--	--	602,000	353,000
United Kingdom	11,000	22,200	960	40,200
Total	23,600,000	8,430,000	17,900,000	6,930,000
Strontium metal:				
Canada	10,400	74,300	3,140	51,800
China	42,800	205,000	181,000	712,000
France	18,000	121,000	--	--
Japan	144,000	667,000	484,000	1,270,000
Korea, Republic of	1,840	2,840	101,000	173,000
Total	217,000	1,070,000	770,000	2,210,000
Strontium nitrate:				
China	226,000	204,000	386,000	300,000
Japan	69,200	426,000	31,000	80,900
Mexico	231,000	169,000	292,000	212,000
Other	--	--	5,350	44,800
Total	527,000	798,000	714,000	637,000
Strontium oxide, hydroxide, peroxide:				
China	83,000	52,900	8,110	18,000
Japan	15,000	22,700	570	17,000
Russia	--	--	5	2,750
Total	98,000	75,600	8,690	37,700

-- Zero.

[1]Data rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship value.

Source: U.S. Census Bureau.

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TABLE 5
CELESTITE: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005
Argentina	3,566 [r, 4]	2,595 [r, 4]	4,300 [r, 4]	6,727 [r, 4]	6,700
China	50,000	100,000	100,000	130,000	140,000
Iran[5]	2,000	2,000	2,100 [r, 4]	7,500 [r, 4]	7,500
Mexico	145,789 [4]	94,015 [4]	130,329 [4]	87,609 [r, 4]	115,214 [P]
Morocco	1,879 [4]	3,780 [4]	2,700	2,700	2,700
Pakistan	2,000	2,000	2,000	2,000	2,000
Spain	129,794 [4]	160,519 [4]	160,000	160,000	160,000
Turkey	63,635 [4]	70,000	70,000	60,000 [r]	60,000
Total	399,000 [r]	435,000	471,000 [r]	457,000 [r]	494,000

[P]Preliminary. [r]Revised.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through May 20, 2006.

[3]In addition to the countries listed, Tajikistan was believed to produce celestite, but information was not available to make reliable estimates.

[4]Reported figure.

[5]Data are for year beginning March 21 of that stated.

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SULFUR

By Joyce A. Ober

Domestic survey data and tables were prepared by Brian W. Jaskula, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

In 2005, for the first time since production was reported in the United States in 1938, recovered sulfur output was significantly lower than it was in 2004. Two devastating hurricanes struck the Gulf Coast region of the United States in August and September, resulting in major refinery shutdowns in Louisiana and Texas; the net effect of the hurricanes was a 6.1% decrease in sulfur recovered from refineries for the year. Sulfur recovered from natural gas operations was down by 9.1% compared with 2004 because of the natural depletion of the sulfur content of natural gas deposits and the successful implementation of an acid-gas reinjection project in Wyoming. Total elemental sulfur production was 6.7% lower than it was in 2004. The reduced recovery from natural gas had been anticipated, but the unanticipated weather-related outages caused significant disruptions in the market.

Even with the unexpectedly low production, the United States was once again the world's leading sulfur producer in 2005 with total production of 9.5 million metric tons (Mt) of sulfur in all forms. All elemental sulfur and byproduct sulfuric acid was produced as a result of efforts to meet environmental requirements that limit atmospheric emissions of sulfur dioxide. Worldwide, compliance with environmental regulations contributed to increased sulfur recovery, although the decreased production in the United States affected output globally. Estimated worldwide production of native sulfur was slightly higher. In the few countries where pyrites remain an important raw material for sulfuric acid production, sulfur production from pyrites increased by 5.5%.

Production continued to outpace sulfur demand, which resulted in increased stocks at some operations, especially at a few in remote locations from which it is difficult and costly to ship the product to market. There was some remelting at more market-accessible stockpiles to meet strong global demand, and the net increase in sulfur stocks was relatively low.

Through its major derivative, sulfuric acid, sulfur ranks as one of the most important elements used as an industrial raw material and is of prime importance to every sector of the world's fertilizer and manufacturing industries. Sulfuric acid production is the major end use for sulfur, and consumption of sulfuric acid has been regarded as one of the best indices of a nation's industrial development. More sulfuric acid is produced in the United States every year than any other inorganic chemical; 37.2 Mt, which is equivalent to about 12.1 Mt of elemental sulfur, was produced in 2005, slightly more than that of 2004 (U.S. Census Bureau, 2006).

In 2005, all salient U.S. sulfur statistics were lower than the corresponding data in 2004. Domestic production and shipments of sulfur in all forms were, respectively, 6.5% and 7.0% lower than those of 2004. Consumption decreased slightly, and exports, imports, prices, stocks, and values were lower (table 1; figures 1-4).

Estimated world sulfur production was the same in 2005 as it was in 2004. Recovered elemental sulfur is produced primarily during the processing of natural gas and crude petroleum. For the past 4 years, an average of 90% of the world's sulfur production came from recovered sources. Some sources of byproduct sulfur are unspecified, which means that the material could be elemental or byproduct sulfuric acid. The quantity of sulfur produced from recovered sources was dependent on the world demand for fuels, nonferrous metals, and petroleum products, rather than for sulfur.

World sulfur consumption was slightly higher than it was in 2004; about 50% was used in fertilizer production, and the remainder, in myriad other industrial uses. World trade of elemental sulfur increased by 7.0% from the levels recorded in 2004. Worldwide inventories of elemental sulfur were relatively unchanged.

Legislation and Government Programs

The U.S. Environmental Protection Agency (EPA) moved the retail compliance date for availability of ultralow sulfur diesel (ULSD) from September 1, 2006, to October 15, 2006, in order to give retailers more time to comply with the 15-part-per-million (ppm) requirement. During this time, 22-ppm diesel will be allowed to be marketed as ULSD to ensure a smooth transition to the lower standard. The EPA will conduct a study to determine if the 2-ppm testing tolerance is adequate (Sulphur, 2005l). Preparations for implementation of the new sulfur requirements for on-road diesel were well underway to meet the October 2006 deadline (Sulphur, 2005c).

The EPA has proposed rules for lower sulfur content in fuels for small marine engines, such as those used in small ships and ferries, and auxiliary engines for larger ships used for electrical power while in port. The proposal limited sulfur content to 0.05% by 2007 and 15-ppm by 2012. The EPA was considering limits for larger vessels that were 30% lower than the sulfur content allowed by the International Maritime Organization's (MARPOL) ratified revised Sea Pollution Prevention Law Annex VI for ships in open oceans and 0.1% sulfur content for fuels burned in port (Sulphur, 2005p).

Another market area that might be addressed soon by regulators is home heating oil. Marketers and regulators began discussions on the possibility of decreasing the sulfur content from the current level of 2,500-ppm to the 15-ppm required for highway diesel beginning in 2006. Although very early in the deliberation process, availability of sufficient supply was the largest concern if new requirements were established close on the heels of prior reductions (Goldstein, 2005).

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Production

Recovered Elemental Sulfur.—U.S. production statistics were collected on a monthly basis and published in the U.S. Geological Survey (USGS) monthly sulfur Mineral Industry Surveys. All of the 107 operations to which survey requests were sent responded; this represented 100% of the total production listed in table 1. In 2005, production and shipments were 6.7% and 7.3% lower than those of 2004, respectively. The value of shipments was 11.6% lower than that in 2004 owing to lower production and decreased average domestic unit value of elemental sulfur. Trends in sulfur production are shown in figures 1 and 3.

The decreased production from petroleum refineries was caused by Hurricanes Katrina and Rita. These storms, which made landfall in the U.S. Gulf Coast area on August 29 and September 24, 2005, respectively, led to decreased sulfur production as a result of precautionary measures taken at oil refineries to prepare for the hurricanes and downtime to repair damage caused by the storms. A total of 28 petroleum refineries were affected to varying degrees by the hurricanes. A few reduced production in preparation for the arrival of either or both storms but quickly resumed full capacity when it became apparent that those facilities were out of danger. Other refineries experienced brief but complete shutdowns as the storms passed. Several refineries were damaged by the storms and remained closed until power was restored and repairs were made (U.S. Department of Energy, 2005§[1]).

As of December 31, all but three of these refineries were operating, most at full capacity. Two refineries were seriously damaged by Hurricane Katrina and remained closed into 2006. ConocoPhillips Co. restarted its Alliance refinery at the end of January 2006, and Murphy Oil Corp. restarted its Meraux refinery in May 2006 (ConocoPhillips Co., 2006, p. 6; Murphy Oil Corp., 2006, p. 21). BP p.l.c.'s Texas City, TX, refinery, the third largest refinery in the United States, was closed in late September 2005 and was not expected to reopen in 2006. Although the refinery was closed in preparation for Hurricane Rita, the extensive repairs were only partially as a result of the storm. The company took advantage of the shutdown to implement extensive maintenance and repairs that were determined necessary during inspections and studies earlier in the year (BP America Inc., 2006§). Total production lost as a result of the hurricanes was estimated to be about 300,000 metric tons (t) (North American Sulphur Review, 2005d).

Recovered elemental sulfur, which is a nondiscretionary byproduct from petroleum-refining, natural-gas-processing, and coking plants, was produced primarily to comply with environmental regulations that were applicable directly to emissions from the processing facility or indirectly by restricting the sulfur content of the fuels sold or used by the facility. Recovered sulfur was produced by 42 companies at 106 plants in 26 States and 1 plant in the U.S. Virgin Islands. The size of the sulfur recovery operations varied greatly from plants producing more than 500,000 metric tons per year (t/yr) to others producing less than 500 t/yr. Of all the sulfur producers canvassed, 35 produced more than 100,000 t of elemental sulfur in 2005, 15 produced between 50,000 and 100,000 t, 36 between 10,000 and 50,000 t, 17 between 1,000 and 10,000 t, and 4 plants produced less than 1,000 t. By source, 79.3% of recovered elemental sulfur production came from petroleum refineries or satellite plants that treated refinery gases and coking plants; the remainder was produced at natural-gas treatment plants (table 3).

The leading producers of recovered sulfur, all with more than 500,000 t of sulfur production, in descending order of production, were Exxon Mobil Corp., Valero Energy Corp., ConocoPhillips, BP, Chevron Corp., Shell Oil Co. (including its joint ventures with Petróleos Mexicanos, S.A. de C.V. and Saudi Refining Inc. and subsidiary operations), CITGO Petroleum Corp. (including the joint-venture refinery it owned with Lyondell Chemical Co.), and Burlington Resources Inc. The 60 plants owned by these companies accounted for 65.4% of recovered sulfur output during the year. Recovered sulfur production by State and district is listed in tables 2 and 3.

Mergers and acquisitions of oil and gas companies that also recover sulfur at their operations resulted in some leading sulfur producers becoming more dominant in 2005. ChevronTexaco Corp., the second ranked oil and gas company in the United States, acquired ninth ranked Unocal Corp. The company later changed its name to Chevron Corp. (Clark, J.R., 2005). Marathon Petroleum Co. LLC adopted its new name after it bought Ashland Inc.'s share of the two companies' joint venture Marathon Ashland Petroleum LLC to become the sole owner of seven refineries in the United States (Nakamura, 2005). Valero acquired Premcor Refining Group Inc. to make it the leading refiner in the United States and the fifth ranked in the world with 18 refineries and crude capacity of 3.3 million barrels per day (Oil & Gas Journal, 2005d). In December, ConocoPhillips announced a proposal to acquire Burlington Resources. ConocoPhillips sulfur production came primarily from oil refining, and Burlington Resources was a major natural gas producer. The transaction was expected to be completed in 2006 (Oil & Gas Journal, 2005a).

Five of the largest refineries in the world are in the United States. The largest U.S. refineries, in decreasing order of capacity, are owned by ExxonMobil in Baytown, TX, and Baton Rouge, LA; Hovensa L.L.C. [(a joint venture of Hess Corp. and Petróleos de Venezuela S.A. (PdVSA)] in St. Croix, VI; BP in Texas City, TX; and CITGO (a wholly owned subsidiary of PdVSA) in Lake Charles, LA (Nakamura, 2005). The capacity to process large quantities of crude oil does not necessarily mean that refineries recover large quantities of sulfur, but all of these refineries were major producers of refinery sulfur. Sulfur production depends on installed sulfur recovery capacity as well as the types of crude oil that are refined at the specific refineries. Major refineries that process low-sulfur crudes may have relatively low sulfur production. According to a survey conducted by Oil & Gas Journal, U.S. refining capacity represents 20.4% of global capacity, but installed sulfur recovery capacity at U.S. oil refineries, which is reported to be 43,700 metric tons per day (t/d) and equivalent to nearly 16 million metric tons per year (Mt/yr); represents 65% of total world refinery capacity for sulfur recovery (Stell, 2005§). A

[1]References that include a section mark (§) are found in the Internet References Cited section.

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survey published by British Sulphur Publishing reported that 14 oil refining companies were in the process of or had recently completed installation of sulfur recovery equipment at 26 refineries in the United States. If all the new sulfur recovery units were operated at full capacity, production of recovered sulfur from those operations could increase by nearly 2.6 Mt/yr (Sulphur, 2005n). Although the hurricanes caused unexpected decreased sulfur recovery in 2005, during the past 10 years, the sulfur content of crude petroleum processes at U.S. refineries has increased owing to increased crude oil imports that typically have higher sulfur content than domestic crudes. This was a major contributing factor to increased sulfur recovery trends from refineries (Swain, 2005).

Byproduct Sulfuric Acid.—Sulfuric acid production at copper, lead, molybdenum, and zinc roasters and smelters accounted for about 7.5% of the total domestic production of sulfur in all forms and totaled 711,000 t; this was a decrease of 3.8% compared with that of 2004 (table 4). Three acid plants operated in conjunction with copper smelters, and four were accessories to lead, molybdenum, and zinc smelting and roasting operations. The three largest sulfuric acid plants were associated with copper mines and accounted for 80.9% of the output. The copper producers—ASARCO LLC, Kennecott Utah Copper Corp., and Phelps Dodge Corp.—each operated a sulfuric acid plant at its primary copper smelter. Kennecott's smelter in Salt Lake City, UT, was shut down for extended periods during the year for maintenance, contributing to reduced production of byproduct sulfuric acid (North American Sulphur Review, 2005b).

In December, Korea Zinc Co. announced that it would close its zinc smelter in Sauget, IL, in February 2006. Although announced as an indefinite closure, it was likely to be permanent, removing 140,000 t/yr of acid from the market, which is equivalent to about 46,000 t/yr of sulfur (North American Sulphur Review, 2005c).

Consumption

Apparent domestic consumption of sulfur in all forms was 3.4% lower than that of 2004 (table 5). Reduced consumption was a result of supply constraints created by the hurricanes, but the decrease was not as significant as the production decline because expanded imports compensated for some of the production shortfall. In addition, the hurricanes had an adverse impact on some of the facilities that normally consume sulfur in the Gulf Coast region, reducing demand in the area. Of the sulfur consumed, 70.0% was obtained from domestic sources—elemental sulfur (65.2%) and byproduct acid (4.9%)—compared with 71.5% in 2004 and 73.3% in 2003. The remaining 30.0% was supplied by imports of recovered elemental sulfur (22.9%) and sulfuric acid (7.1%). The USGS collected end-use data on sulfur and sulfuric acid according to the standard industrial classification of industrial activities (table 6).

Sulfur differs from most other major mineral commodities in that its primary use is as a chemical reagent rather than as a component of a finished product. This use generally requires that it be converted to an intermediate chemical product prior to its initial use by industry. The leading sulfur end use, sulfuric acid, represented 63.1% of reported consumption with an identified end use, and it is reasonable to assume that nearly all of the sulfur consumption reportedly used in petroleum refining was first converted to sulfuric acid, bringing sulfur used in sulfuric acid to 87.9% of the total. Some identified sulfur end uses were included in the "Unidentified" category because these data were proprietary. Data collected from companies that did not identify shipment by end use also were tabulated as "Unidentified." A significant portion of the sulfur in the "Unidentified" category may have been shipped to sulfuric acid producers or exported, although data to support such assumptions were not available.

Because of its desirable properties, sulfuric acid retained its position as the most universally used mineral acid and the most produced and consumed inorganic chemical, by volume. Data based on USGS surveys of sulfur and sulfuric acid producers showed that reported U.S. consumption of sulfur in sulfuric acid (100% basis) increased by 4.7%, and total reported sulfur production decreased slightly. Reported consumption figures do not correlate with calculated apparent consumption owing to reporting errors and possible double counting in some data categories. These data are considered independently from apparent consumption as an indication of market shares rather than actual consumption totals.

Agriculture was the leading sulfur-consuming industry; consumption decreased to 9.05 Mt compared with 9.11 Mt in 2004, but as a percentage of total consumption, agricultural use of sulfur increased to 62.2% from 61.4%. Reported consumption of sulfur in the production of phosphatic fertilizers was slightly higher than that of 2004, but reported consumption of sulfur used in other agricultural chemicals, including sulfur fertilizers, decreased by 8.8%. According to export data from the U.S. Census Bureau (2006), the estimated quantity of sulfur needed to manufacture exported phosphatic fertilizers increased by 9.8% to 3.6 Mt.

The second ranked end use for sulfur was in petroleum refining and other petroleum and coal products. Producers of sulfur and sulfuric acid reported a 13.0% decrease in the consumption of sulfur in that end use. Demand for sulfuric acid in copper ore leaching, which was the third ranked end use, decreased by 12.6% because production of electrowon copper decreased.

The U.S. Census Bureau (2006) also reported that 2.5 Mt of sulfuric acid was produced as a result of recycling spent and contaminated acid from petroleum alkylation and other processes. Two types of companies recycle this material—companies that produce acid for consumption in their own operations and also recycle their own spent acid and companies that provide acid regeneration services to sulfuric acid users. The petroleum refining industry was believed to be the leading source and consumer of recycled acid for use in its alkylation process.

Stocks

Yearend inventories held by recovered elemental sulfur producers decreased to 160,000 t, 13.5% less than those of 2004 (table 1). Based on apparent consumption of all forms of sulfur, combined yearend stocks amounted to less than a 5-day

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supply compared with a 5-day supply in 2004, a 6-day supply in 2003, a 6-day supply in 2002, and an 8-day supply in 2001. Final stocks in 2005 represented 2.8% of the quantity held in inventories at the end of 1976 when sulfur stocks peaked at 5.65 Mt, a 7.4-month supply at that time (Shelton, 1978, p. 1296).

Two companies were installing sulfur-forming, storage, and ship-loading facilities to expand their options for sulfur sales to overseas markets. Much of the sulfur production on the West Coast is formed and shipped overseas, but Gulf Coast producers have been limited to U.S. markets because they have only been able to ship molten sulfur. Gulf Sulphur Services Ltd. was building a facility in Faustina, LA, with a forming capacity of 4,000 t/d. Martin Midstream Partners L.P. was installing equipment capable of forming of 2,000 t/d of sulfur prills at its Neches facility in Beaumont, TX (Sulphur, 2005g).

Prices

The contract prices for elemental sulfur at terminals in Tampa, FL, which are reported weekly in Green Markets, began the year at $61.50 to $64.50 per metric ton. In September, prices increased to $66.50 to $69.50 per ton and increased again in November to $73.00 to $76.00 per ton and remained at that level through the remainder of the year. The price increases in the fall were a direct result of the reduced sulfur production at refineries that were shut down and damaged during the hurricanes.

Based on total shipments and value reported to the USGS, the average value of shipments for all elemental sulfur was estimated to be $30.92 per ton, which was 5.2% lower than that of 2004. Prices vary greatly on a regional basis, which caused the price discrepancies between Green Markets and USGS data. Tampa prices were usually the highest reported in the United States because of the large sulfur demand in the central Florida area. During most of 2005, U.S. west coast prices were listed at $24 to $27 per ton, higher values than what producers have obtained for many years. Nearly all the sulfur produced in this region is processed at forming plants, incurring substantial costs to make solid sulfur in acceptable forms that can be shipped overseas. The majority of west coast sulfur was shipped overseas. Global sulfur prices generally were higher than domestic prices in 2005.

Foreign Trade

Exports of elemental sulfur from the United States, which included the U.S. Virgin Islands, were 27.9% lower in quantity than those of 2004 but only 12.7% lower in value because the average unit value of export material increased to $80.74 per ton (table 7). Exports from the west coast were 405,000 t, or 59.2% of total U.S. exports. Exports from the U.S. Virgin Islands were 103,000 t, or 15.1% of the U.S. total.

The United States continued to be a net importer of sulfur. Imports of elemental sulfur exceeded exports by more than 2.1 Mt. Recovered elemental sulfur from Canada, Mexico, and Venezuela delivered to United States terminals and consumers in the liquid phase furnished 99.5% of all U.S. sulfur import requirements. Total elemental sulfur imports were slightly lower in quantity, and lower prices for imported material resulted in the value being 8.2% lower than it was in 2004. Imports from Canada, mostly by rail, were slightly lower in quantity, waterborne shipments from Mexico were 21.7% lower than those of 2004, and waterborne imports from Venezuela were estimated to increase by a factor of five and account for about 14.5% of all imported elemental sulfur (table 9).

In addition to elemental sulfur, the United States also had significant trade in sulfuric acid. Sulfuric acid exports were 65.4% higher than those of 2004 (table 8). Acid imports were 7.9 times those of exports (tables 8, 10). Canada and Mexico were the sources of 89.6% of United States acid imports, most of which were probably byproduct acid from smelters. Canadian and some Mexican shipments to the United States came by rail, and the remainder of imports came primarily by ship from Chile and Europe. The tonnage of sulfuric acid imports was 11.7% more that of 2004, and the value of imported sulfuric acid increased by 17.4%.

World Industry Structure

The global sulfur industry remained divided into two sectors—discretionary and nondiscretionary. In the discretionary sector, the mining of sulfur or pyrites is the sole objective; this voluntary production of native sulfur or pyrites is based on the orderly mining of discrete deposits with the objective of obtaining as nearly a complete recovery of the resource as economic conditions permit. In the nondiscretionary sector, sulfur or sulfuric acid is recovered as an involuntary byproduct; the quantity of output subject to demand for the primary product irrespective of sulfur demand. Discretionary sources, once the primary sources of sulfur in all forms, represented 10.5% of the sulfur produced in all forms worldwide in 2005 (table 11).

Poland was the only country that produced more than 500,000 t of native sulfur by using either the Frasch or conventional mining methods (table 11). Frasch process is the term for hot-water mining of native sulfur associated with the caprock of salt domes and in sedimentary deposits; in this mining method, the native sulfur is melted underground with superheated water and brought to the surface by compressed air. Small quantities of native sulfur were produced in Asia, Europe, and South America. The importance of pyrites to the world sulfur supply has significantly decreased; China and Finland were the only countries of the top producers whose primary sulfur source was pyrites. About 80.0% of pyrite world production was in China, and 7.0%, in Finland.

Of the 25 countries listed in table 11 that produced more than 500,000 t of sulfur, 18 obtained the majority of their production as recovered elemental sulfur. These 25 countries produced 92.9% of the total sulfur produced worldwide. The international sulfur trade was dominated, in descending order by quantity, by Canada, Russia, Saudi Arabia, the United Arab Emirates, Japan, and Iran; these countries exported more than 1 Mt of elemental sulfur each and accounted for more than 70% of total sulfur trade. Major sulfur importers, in descending order, were China, Morocco, the United States, India, Brazil, and Tunisia, all with imports of more than 1 Mt.

World production of sulfur was the same in 2005 as it was in 2004; consumption was believed to be slightly higher

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than in 2004, but less than production, making 2005 the 14th consecutive year that sulfur production exceeded consumption.

Prices in most of the world were believed to have averaged higher throughout the year than in the previous year, for the third consecutive year. Native sulfur production, including production of Frasch sulfur at Poland's last operating mine, was slightly higher than that of 2004. Recovered elemental sulfur production was slightly lower mostly as a result of the curtailments in the United States, and byproduct sulfuric acid production increased by 3.9% compared with that of 2004. Supplies of sulfur in all forms continued to exceed demand; worldwide sulfur inventories increased slightly, much of which was stockpiled in Canada and Kazakhstan, although Canadian stocks actually declined owing to the strong international demand for sulfur. Globally, production of sulfur from pyrites was 5.4% higher.

According to a survey conducted by Oil & Gas Journal, worldwide refining capacity increased by 3.3% in 2005, although the number of refineries decreased by 2.1%. The largest increases were in Asia and the Middle East, followed by North America, Western Europe, and South America. Refining capacity increases in Eastern Europe were lower, and in Africa, capacity remained level. No regions experienced declines. All increases were a result of expansions at existing refineries; no new refineries began production in 2005. The capacities of the refineries that closed in 2005 were relatively small (Nakamura, 2005).

As the sulfur content of diesel and other fuels decreases, sulfur production from refining increases. Regulations reducing the allowable sulfur content of diesel fuel were being phased in around the world to varying degrees and varying timeframes, but none later than 2010. Europe and Australia have mandated a sulfur content of 10 ppm or less. The United States and Canada require an upper limit of 15-ppm, and the Republic of Korea has set the limit at 30-ppm. China, India, and South Africa have established different standards by regions, some at 50-ppm, others at 350-ppm, and others at 500-ppm. Standards in Latin America range from 50 to 5,000-ppm (Tippee, 2005).

The European Parliament enacted new rules for marine fuels that were to be phased in beginning in May 2006. The sulfur content limit for marine fuels has been reduced to 1.7% (from an average of 2.7% previously) for all ships in the Baltic Sea effective May 19, 2006, and for ships in the North Sea and the English Channel starting in fall 2007. Passenger vessels with regular routes between European ports must meet the earlier deadline, and ships operating on inland waterways and berthed in European Union (EU) ports will be restricted to fuels containing 0.1% sulfur starting January 1, 2010. These changes were expected to reduce sulfur dioxide emissions from ships by 500,000 t/yr. Results will be evaluated in 2008, and depending on the results, more restrictions may then be imposed if the emission reductions are not satisfactory or if the United Nations' Maritime Organization has been successful in implementing reduced sulfur provisions. Between 1990 and 2000, sulfur dioxide from land-based sources in the EU decreased by 60% and was expected to decrease to 20% to 25% of 1990 levels by 2010. Emissions from seagoing ships have increased by 30% (Sulphur, 2005p).

World Review

Canada.—Canada was second only to the United States in production of byproduct sulfur and sulfur in all forms, although total production declined by 5.6% in 2005. The majority of sulfur production came from natural gas plants in Alberta at which production declined, as did recovery at oil sands operations because of a fire at one plant that curtailed production there. Canada led the world in exports of elemental sulfur and stockpiled material. Canadian offshore exports were 6.1 Mt, 3.4% below those of 2004, much of it going to China. For the third consecutive year, strong demand prompted remelting of stocks in Canada, resulting in a decrease of 1 Mt (North American Sulphur Review, 2006). At yearend, Canadian stocks were estimated to be 12 Mt. Much of the remaining stockpiled sulfur is in northern Alberta, from where transportation is difficult and expensive (D'Aquin, 2005).

Alberta has huge deposits of oil sands with estimated reserves of 300 billion barrels of recoverable crude oil that contain 4% to 5% sulfur (Stevens, 1998). The crude oil resource in oil sands in Alberta is larger than the proven reserves of crude oil in Saudi Arabia. As traditional petroleum production in Canada has declined, oil sands have become a more important source of petroleum for the North American market (Pok, 2002, p. 3). Because the bitumen recovered at the oil sands deposits is high-density, high-sulfur petroleum, it must be upgraded to higher quality products or refineries must be adapted to process this type of raw material. Oil sands operations in Alberta continued to expand, including a proposal to increase Suncor Energy, Inc.'s capabilities with the addition of another upgrader, additional sulfur recovery capacity, and increased bitumen supply (Sulphur, 2005o).

China.—China was the world's leading producer of pyrites with 52.0% of sulfur in all forms coming from that source. The country is also the leading sulfur importer. China has become the leading sulfuric acid producer in the world, with 40 Mt in 2004 (the last year for which data is available), an increase of 18.5% from that in 2003. Sulfuric acid production has increased from all sources, but elemental sulfur-base production has increased at a faster rate than pyrites or smelting. Increasing demand for sulfuric acid for the phosphate fertilizer industry in China was expected to drive sulfuric acid production to 53 Mt in 2010, with 48% sulfur-base, 30% from pyrites, and 21% from smelter acid. Recovered sulfur production, still relatively low in China, was 827,000 t in 2004, but was expected to approach 2 Mt in 2010 (Cunningham, 2005).

Environmental regulations in China were beginning to address the air-quality issues faced in that country. Sulfur dioxide emissions from coal-fired powerplants were expected to reach nearly 20 Mt in 2005. The Government of China developed a plan to reduce emissions at 31 of the country's largest coal burners (Sulphur, 2005j). A new metallurgical coke plant was engineered to include desulfurization and sulfur recovery technology. Although the sulfur recovery will be relatively low at about 20 t/d (7,300 t/yr), this type of development is an indicator of increased environmental awareness in China (Sulphur, 2005m).

Iran.—Increased recovery of associated gas (natural gas found in crude petroleum deposits either dissolved in the oil or trapped

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as free gas above the oil) in Iran will result in addition sulfur production and exports. The Amak Project in southern Iran that has the capacity to recover 180 t/d of elemental sulfur was completed in September (Sulphur, 2005e). The fourth and fifth phases of development of the South Pars gasfield off the coast of Iran were completed and began production of natural gas, gas condensate, and 400 t/d of sulfur. The gasfield, which is to be developed in 24 phases, is thought to contain more than 8% of the world's gas reserves and more than 50% of Iran's (Sulphur, 2005q).

Sulfur exports from Iran were 650,000 t in 2004 but are expected to increase significantly with the completion of additional phases at the South Pars gasfield that have a combined capacity of 600 t/d (219,000 t/yr) along with 400,000 t/yr of additional export material from the Khangiran gasfield. (Cunningham, 2005).

Poland.—The single remaining Frasch sulfur mine operating in the world is the Osiek Mine in Poland that opened in 1993. Reserves at Osiek were estimated to be 36 Mt with production capacity of 800,000 t/yr. Most of the production was exported to Morocco for use in phosphate fertilizer production (King, 2005).

Qatar.—Qatar Liquefied Gas Company Ltd. (Qatargas) operated a liquefied natural gas (LNG) plant in Ras Laffan Industrial City fed by the offshore North Field, the world's largest nonassociated natural gas field. Qatargas produced 450 t/d (164,000 t/yr) of granulated sulfur in 2005, but plans for huge expansions in LNG production will result in additional sulfur production, eventually expected to reach 12,000 t/d (4.4 Mt/yr). No reinjection of acid gases was planned at this project (Cunningham, 2005).

Russia.—Russia's Astrakhangazprom, LLC was the world's leading sulfur producing company. It produced sulfur at the Astrakhan gas processing plant from eight sulfur recovery plants each with the capacity to produce about 80 metric tons per hour. Recent sulfur developments at Astrakhan have focused on improving the quality of the product through installation of forming equipment to minimize the sales of crushed and broken sulfur, replacing it with pelletized sulfur with a low acidity level (Sulphur, 2005b).

Saudi Arabia.—Sulfur recovery was expected to increase dramatically in Saudi Arabia in the next few years. Sulfur recovery units planned for gas processing plants were expected to have the capacity to recover nearly 3 Mt/yr of elemental sulfur. An example of such an operation is the Khursaniyah gas plant that was being developed to process the natural gas from the Abu Hadriya, Fadhili, and Khursaniyah oilfields near Jubail. Development of these oilfields was expected to result in the production of large quantities of crude oil, natural gas, ethane, natural gas liquids, and 1,800 t/d (657,000 t/yr) of elemental sulfur (Oil & Gas Journal, 2005c; Sulphur, 2005h).

Saudi Arabian Oil Co. planned to build a refinery in Yanbu to supply international markets, possibly with investments from Indian refiners. Lack of capacity in India for refining high-sulfur crude oils has been a major factor in increased energy costs in recent years. Indian participation will relieve some of the pressure in India for low-sulfur fuel supplies. Other international markets could include the United States east coast, Europe, and other parts of Asia. Sulfur will be recovered at the refinery (Sulphur, 2005a).

Although much of the additional sulfur produced at these operations will be exported, a new project was under development that was expected to consume domestic sulfur in Saudi Arabia. A large phosphate fertilizer project was planned that could consume more than 4,000 t/d (1.46 Mt/yr) of sulfur to produce the sulfuric acid required (Cunningham, 2005).

United Arab Emirates.—Activities were in progress to increase sulfur recovery and handling in the United Arab Emirates by 2007. The sulfur recovery capacity at Abu Dhabi Gas Industries' Habshan Gas Complex was to be expanded with the installation of two sulfur recovery units with the combined capacity of 1,600 t/d (580,000 t/yr). Abu Dhabi Oil Refining Co. planned to expand its terminal at Ruwais by installing granulation capacity, expanding liquid and solid sulfur storage facilities, replacing existing granulation units, constructing truck unloading stations, and building a new export jetty. Construction was expected to take about 21 months (Middle East Economic Digest, 2005; Sulphur, 2005d).

Venezuela.—Sulfur recovery capacity in operation or under construction at heavy oil upgraders in Venezuela was almost 1 Mt/yr in 2005, most of which was exported. Additional projects to increase petroleum production from the Orinoco Belt have the potential of increasing sulfur production by a factor of five or more. PdVSA announced plans to build three refineries in Barinas, Caripito, and Cabruta, all of which will process heavy high-sulfur crude petroleum from the Orinoco Belt. During the refining, an additional 500,000 t of elemental sulfur is likely to be recovered (North American Sulphur Review, 2005b). Political issues, however, may limit foreign involvement in these projects. The Organic Hydrocarbons Law, enacted in 2002, requires more than 50% Government control of projects involving foreign companies. The law raised the highest royalty to 30% from a previous high of 16.7%. Joint-venture ownership rules have limited the lifetime of the agreements to 25 years, down from 35 years for the first agreements, although these terms may be renegotiated. The early agreements for developing heavy-oil upgraders were more attractive to foreign investors. The more restrictive law may make it uneconomic for foreign investors to participate in future projects (Sulphur, 2005k).

PdVSA has warned that foreign companies that do not agree to new terms for their Venezuela ventures risked total takeover by the Venezuelan company. The new agreements would give PdVSA 60% to 80% interests with 25-year partnerships in projects in which the foreign companies are already involved (Sulphur, 2005f). In addition, officials in Venezuela were considering the sale of PdVSA's United States subsidiary CITGO because the company did not represent a significant benefit to the people of Venezuela (North American Sulphur Review, 2005a).

Current Research and Technology

One common method for stockpiling excess sulfur is in blocks, where molten sulfur is poured into forms, which then cool to form large solid masses of elemental sulfur. Sulfur can be emitted in several ways from these blocks when left exposed to the atmosphere. Small, but significant quantities of sulfuric acid result from microbial activity and rainfall. Very

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small quantities of hydrogen sulfide and sulfur dioxide may be released from the surfaces of freshly poured sulfur blocks. Weathered blocks are a source of wind-blown sulfur dust, and in very hot conditions, sulfur can sublime into the atmosphere, becoming part of the global sulfur cycle.

Alberta Sulfur Research Ltd. (ASR) proposed a very simple method to minimize these emissions. The proposed method entailed covering the horizontal surfaces of sulfur blocks with golf-ball-sized pieces of limestone or broken concrete to reflect sunlight, keeping surface temperatures lower to minimize sublimation, protecting the surface from weathering, and neutralizing any sulfuric acid that might form. ASR also determined that the addition of a surfactant to molten sulfur reduces cracking when it solidifies, limiting the effects of moisture on the block (Clark, Peter, 2005).

Outlook

Although sulfur production was lower in 2005, the industry was expected to resume its trends toward increased production, slow growth in consumption, higher stocks, and expanded world trade. U.S. production from petroleum refineries was expected to recover quickly to pre-2005 levels and increase substantially in the next few years as expansions, upgrades, and new facilities at existing refineries are completed. The expansions were enabling refiners to increase throughput of crude oil and to process higher sulfur crudes; additional sulfur production will be a byproduct of refining upgrades. Production from natural gas operations is expected to be substantially lower in 2006 as a result of declines in production, especially from Wyoming, the source of 72.0% of all domestic gas-derived sulfur recovery. Sulfur recovered from natural gas could decrease up to 450,000 t/yr owing to the successful implementation of a reinjection project at ExxonMobil's Wyoming plant (D'Aquin, 2005). The reinjection process increased gas inlet capacity, and reduced carbon dioxide venting, sulfur dioxide emissions, and sulfur handling costs. The old sulfur recovery unit had high operating expenses and maintenance costs (Oil & Gas Journal, 2005b). Depletion at other fields as a natural function of long-term extraction of natural gas is likely to result in a further decrease of 100,000 t/yr from that source (D'Aquin, 2005). Burlington Resources recently expanded its operation in Wyoming but had the option of storing excess production underground if the markets were not favorable for sales. Theoretically, this material would be available to meet future needs. In reality, however, it was more likely to represent an option for disposing of unwanted surplus material.

Worldwide recovered sulfur output is expected to increase significantly in the future. For the next 2 or 3 years, sulfur supply and demand is expected to be reasonably well balanced. Severe sulfur surpluses, however, are expected beginning in 2010 with acceleration thereafter as a result of increased production, especially from oil sands in Canada, natural gas in the Middle East, expanded oil and gas operations in Kazakhstan, and Venezuela's heavy-oil processors (Sulphur, 2005i).

Additional increases will come from Russia's growth in sulfur recovery from natural gas and Asia's improved sulfur recovery at oil refineries. Refineries in developing countries should begin to improve environmental protection measures and, in the future, eventually approach the environmental standards of plants in Japan, North America, and Western Europe.

The world demand for natural gas is expected to maintain strong growth, and sulfur recovery from that sector will continue to increase. Future gas production, however, is likely to come from deeper, hotter, and more sour deposits that will result in even more excess sulfur production unless more efforts are made to develop new large-scale uses for sulfur. Other alternative technologies for reinjection and long-term storage to eliminate some of the excess sulfur supply will require further investigation to handle the quantity of surplus material anticipated (Hyne, 2000).

Byproduct sulfuric acid production will remain relatively steady in the United States as long as the copper smelters remain idle or no additional smelters close. With the copper industry's switch to lower cost production processes and producing regions, the idle smelters may never reopen.

Worldwide, the outlook is different. Because copper production costs in some countries are lower than in the United States, acid production from those countries has increased, and continued increases are likely. Many copper producers have installed more efficient sulfuric acid plants to limit sulfur dioxide emissions at new and existing smelters. Byproduct sulfuric acid production is expected to increase to 70.3 Mt in 2014 from about 47 Mt in 2005. Worldwide, sulfur emissions at nonferrous smelters have declined as a result of improved sulfur recovery; increased byproduct acid production is likely to become more a function of metal demand than a function of improved recovery technology. One-half of the projected increase of byproduct acid production will likely be from smelters in China, with additional quantities from Chile and Peru, although production from all regions was expected to increase (Sulphur, 2005i).

Frasch sulfur and pyrites production, however, have little chance of significant long-term increases, although higher sulfur prices have resulted in temporary increases in pyrites production and consumption. Because of the continued growth of elemental sulfur recovery for environmental reasons rather than demand, discretionary sulfur has become increasingly less important as demonstrated by the decline of the Frasch sulfur industry. The Frasch process has become the high-cost process for sulfur production. Pyrites, with significant direct production costs, is an even higher cost raw material for sulfuric acid production when the environmental aspects are considered. Discretionary sulfur output should show a steady decline. The decreases will be pronounced when large operations are closed outright for economic reasons, as was the case in 2000 and 2001.

Sulfur and sulfuric acid will continue to be important in agricultural and industrial applications, although consumption will be less than production. Because sulfuric acid consumption for phosphate fertilizer production was expected to increase at a lower rate than some other uses, phosphate may become less dominant in sulfur consumption but remain the leading end use. Ore leaching will be the largest area of sulfur consumption growth (Sulphur, 2005i). World sulfur demand for fertilizer is forecast to increase by 2.1% per year for the next 10 years; industrial demand is predicted to grow by 2.2% per year as a result of increased demand for copper and nickel leaching.

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The most important changes in sulfur consumption will be in location. Phosphate fertilizer production, where the most sulfur is consumed, is projected to increase by 1.9% per year through 2014. With new and expanding phosphate fertilizer capacity in Australia, China, Egypt, India, and Saudi Arabia, sulfur demand will grow in these areas at the expense of some phosphate operations elsewhere, transferring sulfur demand rather than creating new demand. The effects were already being felt by the U.S. phosphate industry as reflected in the permanent closure of some facilities and reduced production at others. U.S. phosphate products supply domestic requirements, but a large portion of U.S. production is exported. Brazil, China, and India are primary markets for United States phosphatic fertilizers. As the phosphate fertilizer industries develop in these countries, some of the markets for U.S. material could be lost. Sulfur will be required for phosphate production at new operations, and more sulfur producers will be competing for those markets.

Use of sulfur directly or in compounds as fertilizer is expected to increase, but this use will be dependent on agricultural economies and increased acceptance of the need for sulfur in plant nutrition. If widespread use of plant nutrient sulfur is adopted, then sulfur consumption in that application could grow significantly; thus far, however, growth has been slow.

Industrial sulfur consumption has some prospects for growth, but not enough to consume all projected surplus production. Conversion to or increases in copper leaching by producers that require significantly more sulfuric acid for the leaching operations than was used in 2005 bode well for the sulfur industry. Nickel pressure acid leach operations were demanding increased quantities of sulfur, and more projects have been announced globally. Changes in the preferred methods for producing oxygenated gasoline, especially in Canada and the United States, might result in additional alkylation capacity that would require additional sulfuric acid. Other industrial uses show less potential for expansion. Production is expected to surpass demand well into the future.

Unless less traditional uses for elemental sulfur increase significantly, the oversupply situation will result in tremendous stockpiles accumulating around the world. In the 1970s and 1980s, research was conducted that showed the effectiveness of sulfur in several construction uses that held the promise of consuming huge quantities of sulfur in sulfur-extended asphalt and sulfur concretes. In many instances, these materials were found to be superior to the more conventional products, but their use so far has been very limited. When sulfur prices are high, as they were in 2005, sulfur is less attractive for unconventional applications where low-cost raw materials are the important factor.

Regardless of the prevailing price increases in 2005 that signaled tight supplies, the worldwide oversupply situation is likely to continue. Unless measures are taken to use more sulfur, either voluntarily or through government mandate, large quantities of excess sulfur could be amassed in many areas of the world, including the United States.

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TABLE 1
SALIENT SULFUR STATISTICS[1]

(Thousand metric tons of sulfur content and thousand dollars unless otherwise specified)

	2001	2002	2003	2004	2005
United States:					
Quantity:					
Production:					
Frasch	--	--	--	--	--
Recovered[2]	8,490	8,500	8,920	9,380	8,750
Other	982	772	683	739	711
Total[e]	9,470	9,270	9,600	10,100	9,460
Shipments:					
Frasch	--	--	--	--	--
Recovered[2]	8,470	8,490	8,910	9,410	8,720
Other	982	772	683	739	711
Total	9,450	9,260	9,600	10,100	9,430
Exports:					
Elemental[3]	711	709	840	949	684
Sulfuric acid	69	48	67	67	110
Imports:					
Elemental	1,730	2,560	2,870 [e]	2,850 [e]	2,820 [e]
Sulfuric acid	462	346	297	784	877
Consumption, all forms[4]	10,900	11,400	11,900	12,800	12,300
Stocks, December 31, producer, Frasch and recovered	232	181	206	185	160
Value:					
Shipments, free on board (f.o.b.) mine or plant:					
Frasch	--	--	--	--	--
Recovered[e, 2]	84,700	100,000	256,000	306,000	270,000
Other	49,500	35,500	34,000	61,100	80,200
Total	134,000	136,000	290,000	367,000	351,000
Exports, elemental[5]	52,000	43,100	54,400	63,300	55,200
Imports, elemental	22,100	26,800	70,600	76,800	70,500
Price, elemental, f.o.b. mine or plant[e] dollars per metric ton	9.99 [r]	11.82 [r]	28.70 [r]	32.62 [r]	30.92
World, production, all forms (including pyrites)	61,400 [r]	62,600 [r]	64,200 [r]	66,000 [r]	66,000 [e]

[e]Estimated. [r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits except prices; may not add to totals shown.

[2]Includes U.S. Virgin Islands.

[3]Includes exports from the U.S. Virgin Islands to foreign countries.

[4]Consumption is calculated as shipments minus exports plus imports.

[5]Includes value of exports from the U.S. Virgin Islands to foreign countries.

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TABLE 2

RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY STATE[1]

(Thousand metric tons and thousand dollars)

State	2004			2005		
		Shipments			Shipments	
	Production	Quantity	Value[e]	Production	Quantity	Value[e]
Alabama	228	228	7,560	236	236	9,420
California	1,050	1,050	20,500	1,080	1,040	26,500
Illinois	528	528	10,400	567	568	13,700
Louisiana	1,280	1,280	72,600	1,150	1,150	36,600
Michigan and Minnesota	35	38	1,040	35	35	974
Mississippi	495	501	19,800	409	404	17,900
New Mexico	34	34	(2)	32	32	(2)
Ohio	122	122	3,610	111	111	3,480
Texas	3,100	3,090	110,000	2,830	2,840	110,000
Washington	113	113	(2)	137	137	(2)
Wyoming	1,540	1,540	24,200	1,300	1,310	23,900
Other[3]	849	886	36,300	856	865	27,500
Total	9,380	9,410	306,000	8,750	8,720	270,000

[e]Estimated.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Some sulfur producers in this State incur expenses to make their products available to consumers.

[3]Includes Arkansas, Colorado, Delaware, Florida, Indiana, Kansas, Kentucky, Montana, New Jersey, North Dakota, Pennsylvania, Utah, Virginia, Wisconsin, and the U.S. Virgin Islands.

TABLE 3

RECOVERED SULFUR PRODUCED AND SHIPPED IN THE UNITED STATES, BY PETROLEUM ADMINISTRATION FOR DEFENSE (PAD) DISTRICT[1]

(Thousand metric tons)

District and source	2004		2005	
	Production	Shipments	Production	Shipments
PAD 1:				
Petroleum and coke	236	238	234	235
Natural gas	21	21	19	18
Total	256	259	253	253
PAD 2:				
Petroleum and coke	976	978	1,040	1,040
Natural gas	43	43	36	36
Total	1,020	1,020	1,070	1,070
PAD 3:[2]				
Petroleum and coke	4,780	4,810	4,320	4,330
Natural gas	512	510	491	490
Total	5,300	5,320	4,810	4,820
PAD 4 and 5:				
Petroleum and coke	1,390	1,400	1,350	1,310
Natural gas	1,410	1,420	1,260	1,270
Total	2,800	2,810	2,610	2,580
Grand total	9,380	9,410	8,750	8,720
Of which:				
Petroleum and coke	7,390	7,420	6,940	6,910
Natural gas	1,990	1,990	1,810	1,810

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes the U.S. Virgin Islands.

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TABLE 4
BYPRODUCT SULFURIC ACID PRODUCED IN THE UNITED STATES[1, 2]

(Thousand metric tons of sulfur content and thousand dollars)

Type of plant	2004	2005
Copper[3]	600	575
Zinc, lead, and molybdenum[4]	138	137
Total:		
Quantity	739	711
Value	61,100	80,200

[1]May include acid produced from imported raw materials.
[2]Data are rounded to no more than three significant digits, may not add to totals shown.
[3]Excludes acid made from pyrites concentrates.
[4]Excludes acid made from native sulfur.

TABLE 5
CONSUMPTION OF SULFUR IN THE UNITED STATES[1, 2, 3]

(Thousand metric tons)

	2004	2005
Elemental sulfur:		
Shipments[4]	9,410	8,720
Exports	949	684
Imports[e]	2,850	2,820
Total	11,300	10,900
Byproduct sulfuric acid:		
Shipments[4]	739	711
Exports[5]	67	110
Imports[5]	784	877
Total	1,460	1,480
Grand total	12,800	12,300

[e]Estimated.
[1]Crude sulfur or sulfur content.
[2]Data are rounded to no more than three significant digits; may not add to totals shown.
[3]Consumption is calculated as shipments minus exports plus imports.
[4]Includes the U.S. Virgin Islands.
[5]May include sulfuric acid other than byproduct.

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TABLE 6

SULFUR AND SULFURIC ACID SOLD OR USED IN THE UNITED STATES, BY END USE[1]

(Thousand metric tons of sulfur content)

SIC[3]	End use	Elemental sulfur[2]		Sulfuric acid (sulfur equivalent)		Total	
		2004	2005	2004	2005	2004	2005
102	Copper ores	--	--	452	395	452	395
1094	Uranium and vanadium ores	--	--	2	7	2	7
10	Other ores	--	--	6	53	6	53
26, 261	Pulpmills and paper products	W	W	272	267	272	267
28, 285, 286, 2816	Inorganic pigments, paints, and allied products; industrial organic chemicals, other chemical products[4]	W	W	154	312	154	312
281	Other inorganic chemicals	W	W	108	109	108	109
282, 2822	Synthetic rubber and other plastic materials and synthetics	--	W	70	64	70	64
2823	Cellulosic fibers including rayon	--	--	2	--	2	--
283	Drugs	--	--	1	1	1	1
284	Soaps and detergents	--	--	2	7	2	7
286	Industrial organic chemicals	--	--	25	17	25	17
2873	Nitrogenous fertilizers	--	--	209	214	209	214
2874	Phosphatic fertilizers	--	--	6,870	7,000	6,870	7,000
2879	Pesticides	--	--	16	15	16	15
287	Other agricultural chemicals	1,970	1,770	49	48	2,010	1,810
2892	Explosives	--	--	10	10	10	10
2899	Water-treating compounds	--	--	89	67	89	67
28	Other chemical products	--	--	105	290	105	290
29, 291	Petroleum refining and other petroleum and coal products	4,100	3,590	248	188	4,350	3,780
30	Rubber and miscellaneous plastic products	W	W	4	3	4	3
331	Steel pickling	--	--	9	52	9	52
333	Nonferrous metals	--	--	3	4	3	4
33	Other primary metals	--	--	6	10	6	10
3691	Storage batteries (acid)	--	--	29	16	29	16
	Exported sulfuric acid	--	--	26	26	26	26
	Total identified	6,070	5,360	8,770	9,180	14,800	14,500
	Unidentified	801	608	518	503	1,320	1,110
	Grand total	6,870	5,970	9,290	9,680	16,200	15,600

W Withheld to avoid disclosing company proprietary data; included with "Unidentified." -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Does not include elemental sulfur used for production of sulfuric acid.

[3]Standard industrial classification.

[4]No elemental sulfur was used in inorganic pigments, paints, and allied products.

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TABLE 7
U.S. EXPORTS OF ELEMENTAL SULFUR, BY COUNTRY[1, 2]

(Thousand metric tons and thousand dollars)

Country	2004		2005	
	Quantity	Value	Quantity	Value
Argentina	12	604	59	3,000
Brazil	520	31,800	165	11,800
Canada	88	6,070	110	8,610
Chile	24	1,700	3	928
China	167	9,880	248	20,200
Colombia	19	1,380	6	561
Mexico	24	1,960	31	1,950
Morocco	35	1,740	15	491
Senegal	18	896	18	1,690
Switzerland	19	1,090	12	608
Venezuela	1	1,370	3	1,190
Other	22 r	4,810 r	14	4,250
Total	949	63,300	684	55,200

rRevised.

[1]Includes exports from the U.S. Virgin Islands.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 8
U.S. EXPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY[1]

Country	2004		2005	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Aruba	2,630	$217	1,740	$399
Brazil	17	15	49,400	2,040
Canada	98,700	7,730	101,000	8,120
Chile	8,270	942	--	--
China	2,050	562	2,320	449
Dominican Republic	2,410	279	6,970	562
Germany	394	45	6,530	1,240
Ireland	3,490	1,530	2,360	1,190
Israel	236	349	257	355
Italy	4	17	2,810	322
Japan	67	118	3,920	623
Korea, Republic of	157	18	3,200	436
Malaysia	64	44	6,700	954
Mexico	44,100	2,190	3,000	683
Netherlands Antilles	10,200	484	12,000	633
Saudi Arabia	2,230	4,020	375	1,010
Singapore	52	55	11,600	1,600
Taiwan	595	454	15,700	2,190
Trinidad and Tobago	6,520	395	18,000	908
United Kingdom	142	24	371	333
Venezuela	16,800	849	86,500	4,570
Other	5,110 r	982 r	3,130	854
Total	204,000	21,300	338,000	29,500

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 9

U.S. IMPORTS OF ELEMENTAL SULFUR, BY COUNTRY[1]

(Thousand metric tons and thousand dollars)

	2004		2005	
Country	Quantity	Value[2]	Quantity	Value[2]
Canada	2,010 e	31,300	1,970 e	33,500
Mexico	545	28,200	427	18,600
Venezuela	80 e	16,100	409 e	16,800
Other	215 r,e	1,200 r	14 e	1,600
Total	2,850 e	76,800	2,820 e	70,500

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Declared customs valuation.

Source: U.S. Census Bureau and PentaSul North American Sulphur Service as adjusted by the U.S. Geological Survey.

TABLE 10

U.S. IMPORTS OF SULFURIC ACID (100% H_2SO_4), BY COUNTRY[1]

	2004		2005	
Country	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
Canada	1,920,000	$79,400	2,010,000	$89,400
Chile	--	--	100,000	5,380
Mexico	217,000	5,670	398,000	9,440
Other	263,000 r	19,200 r	178,000	18,100
Total	2,400,000	104,000	2,680,000	122,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Declared cost, insurance, and freight paid by shipper valuation.

Source: U.S. Census Bureau.

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TABLE 11

SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1, 2]

(Thousand metric tons)

Country and source[3]	2001	2002	2003	2004	2005[e]
Australia, byproduct:[e]					
Metallurgy	817	899	863	865	950
Petroleum	45	60	60	60	60
Total	862	959	923	925	1,010
Canada, byproduct:					
Metallurgy	1,124 r	1,109 r	992 r	1,089 r	1,057 p
Natural gas, petroleum, tar sands	8,320 r	7,816 r	8,036 r	8,421 r	7,916 p
Total	9,444 r	8,925 r	9,028 r	9,510 r	8,973 p
Chile, byproduct, metallurgy[e]	1,160	1,275 [4]	1,430	1,510	1,660
China:[e]					
Elemental	420 r	540 r	700 r	820 r	900
Pyrites	3,090	3,240	3,400	3,730	4,010
Byproduct, metallurgy	2,000	2,200	2,400	2,600	2,800
Total	5,510 r	5,980 r	6,500 r	7,150 r	7,710
Finland:[e]					
Pyrites	270	359	341	336	350
Byproduct:					
Metallurgy	227	308	305	301	300
Petroleum	46	55	60	65	70
Total	543	722	706	702	720
France, byproduct:[e]					
Natural gas and petroleum	837	787	816	765	750
Unspecified	260	229	196	196	195
Total	1,100	1,020	1,010	961	945
Germany:					
Pyrites	-- r	--	--	--	--
Unspecified, marketable	988	1,093	1,014	939	940
Byproduct:					
Metallurgy	684	754	701	591	600
Natural gas and petroleum	1,749	1,745	1,661	977 r	977
Total	3,421 r	3,592 r	3,376 r	2,506 r	2,520
India:[e]					
Pyrites	32	32	32	32	32
Byproduct:					
Metallurgy	458	458	539	539	580
Natural gas and petroleum	526	371	451	501	520
Total	1,020	861	1,020	1,070	1,130
Iran, byproduct:[e]					
Metallurgy	50	50	50	60	60
Natural gas and petroleum	880 [4]	1,200 [4]	1,310	1,400	1,400
Total	930	1,250	1,360	1,460	1,460
Italy, byproduct:[e]					
Metallurgy	203	142	127	113	115
Petroleum	540	560	565	575	570
Total	743	702	692	688	685
Japan, byproduct:					
Metallurgy	1,319	1,326	1,281	1,263	1,330
Petroleum	2,424	1,865	1,951	1,895 r	1,930
Total	3,743	3,191	3,232	3,158 r	3,260

See footnotes at end of table.

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TABLE 11—Continued
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1, 2]

(Thousand metric tons)

Country and source[3]	2001	2002	2003	2004	2005[e]
Kazakhstan, byproduct:[e]					
Metallurgy	310	260	325	325	325
Natural gas and petroleum	1,400	1,600	1,600	1,650	1,700
Total	1,710	1,860	1,930	1,980	2,030
Korea, Republic of, byproduct:[e]					
Metallurgy	665	737	797 [r]	796	800
Petroleum	690	687	757	879	885
Total	1,360	1,420	1,550 [r]	1,680	1,690
Kuwait, byproduct, natural gas and petroleum[e]	524	634	714	682	700
Mexico, byproduct:					
Metallurgy[e]	572	588	539	703	700
Natural gas and petroleum	878	877	1,052	1,122	1,017 [4]
Total	1,450	1,465	1,591	1,825	1,717 [4]
Netherlands, byproduct:[e]					
Metallurgy	126	124	131	137	135
Petroleum	384	373	408	410	400
Total	510	497	539	547	535
Poland:[5]					
Frasch	942	760	762 [e]	750 [e]	750
Byproduct:					
Metallurgy[e]	277 [4]	276 [r]	294 [r]	290 [r]	280
Petroleum	133	180	180 [r, e]	190 [r, e]	190
Total[e]	1,352 [4]	1,220 [r]	1,240 [r]	1,230 [r]	1,220
Russia:[e, 6]					
Native	50	50	50	50	50
Pyrites	320	350	350	300	300
Byproduct:					
Metallurgy	460	500	520	570	600
Natural gas	5,300	5,600	5,800	6,000	6,000
Total	6,130	6,500	6,720	6,920	6,950
Saudi Arabia, byproduct, all sources[e]	2,350	2,360	2,180	2,230	2,300
South Africa:					
Pyrites, S content, from gold mines	150	183	176	165	133 [p]
Byproduct:					
Metallurgy, copper, platinum, zinc plants	265 [e]	179	174	180	250
Petroleum	123	170	264	288	410
Total	538	532	614	633	793
Spain:[e]					
Pyrites	71	--	--	--	--
Byproduct:					
Coal, lignite, gasification	1	1	1	1	1
Metallurgy	461	544	560	488	475
Petroleum	135	140	145	145	140
Total	668	685	706	634	616
United Arab Emirates, byproduct, natural gas and petroleum[e]	1,490	1,900	1,900	1,930	1,950
United States, byproduct:					
Metallurgy	982	772	683	739	711 [4]
Natural gas	2,000	1,760	1,940	1,990	1,810 [4]

See footnotes at end of table.

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TABLE 11—Continued
SULFUR: WORLD PRODUCTION IN ALL FORMS, BY COUNTRY AND SOURCE[1, 2]

(Thousand metric tons)

Country and source[3]	2001	2002	2003	2004	2005[e]
United States, byproduct—Continued:					
Petroleum	6,480	6,750	6,970	7,390	6,940 [4]
Total	9,470	9,270	9,600	10,100	9,460 [4]
Uzbekistan, byproduct:[e]					
Metallurgy	160	170	170	170	170
Natural gas and petroleum	300	350	350	350	350
Total	460	520	520	520	520
Venezuela, byproduct, natural gas and petroleum	340	570	560 [e]	800 [e]	800
Other[e]	4,630 [r]	4,700 [r]	4,570 [r]	4,640 [r]	4,660
Of which:					
Frasch	24	23	19	20	20
Native[7]	523 [r]	502 [r]	283 [r]	251 [r]	217
Pyrites	214 [r]	189 [r]	200 [r]	192 [r]	187
Unspecified	1,120	1,090	1,140	1,150 [r]	1,190
Of which:					
Byproduct:					
Metallurgy	1,260 [r]	1,320 [r]	1,380 [r]	1,350 [r]	1,350
Natural gas	226	255	305	365	365
Natural gas and petroleum, undifferentiated	420 [r]	441 [r]	405 [r]	425 [r]	427
Petroleum	845 [r]	882 [r]	843 [r]	881 [r]	900
Grand total	61,400 [r]	62,600 [r]	64,200 [r]	66,000 [r]	66,000
Of which:					
Frasch	966	783	781	770	770
Native[7]	993 [r]	1,090 [r]	1,030 [r]	1,120 [r]	1,170
Pyrites	4,150 [r]	4,350 [r]	4,500 [r]	4,760 [r]	5,010
Unspecified	4,720 [r]	4,780 [r]	4,530 [r]	4,510 [r]	4,630
Byproduct:					
Coal, lignite, gasification[e]	1	1	1	1	1
Metallurgy	13,600 [r]	14,000 [r]	14,300 [r]	14,700 [r]	15,300
Natural gas	7,530 [r]	7,610 [r]	8,050 [r]	8,360 [r]	8,170
Natural gas, petroleum, tar sands, undifferentiated	17,700 [r]	18,300 [r]	18,900 [r]	19,000 [r]	18,500
Petroleum	11,800 [r]	11,700 [r]	12,200 [r]	12,800 [r]	12,500

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 17, 2006.

[3]The term "source" reflects the means of collecting sulfur and the type of raw material. Sources listed include the following: Frasch recovery; native comprising all production of elemental sulfur by traditional mining methods (thereby excluding Frasch); pyrites (whether or not the sulfur is recovered in the elemental form or as acid); byproduct recovery, either as elemental sulfur or as sulfur compounds from coal gasification, metallurgical operations including associated coal processing, crude oil and natural gas extraction, petroleum refining, tar sand cleaning, and processing of spent oxide from stack-gas scrubbers; and recovery from processing mined gypsum. Recovery of sulfur in the form of sulfuric acid from artificial gypsum produced as a byproduct of phosphatic fertilizer production is excluded, because to include it would result in double counting. Production of Frasch sulfur, other native sulfur, pyrite-derived sulfur, mined gypsum derived sulfur, byproduct sulfur from extraction of crude oil and natural gas, and recovery from tar sands are all credited to the country of orgin of the extracted raw materials. In contrast, byproduct recovery from metallurgical operations, petroleum refineries, and spent oxides are credited to the nation where the recovery takes place, which is not the original source country of the crude product from which the sulfur is extracted.

[4]Reported figure.

[5]Government of Poland sources report total Frasch and native mined elemental sulfur output annually, undifferentiated; this figure has been divided between Frasch and other native sulfur on the basis of information obtained from supplementary sources.

[6]Sulfur is believed to be produced from Frasch and as a petroleum byproduct; however, information is inadequate to formulate estimates.

[7]Includes "China, elemental."

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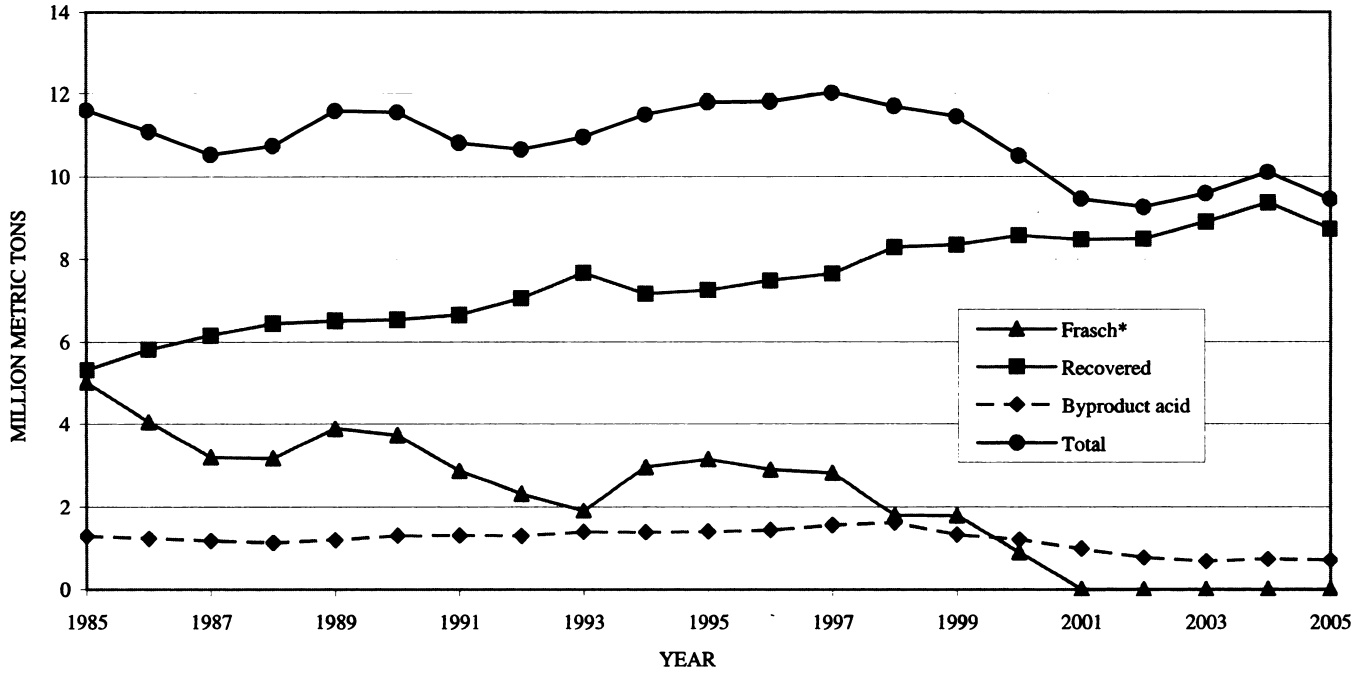
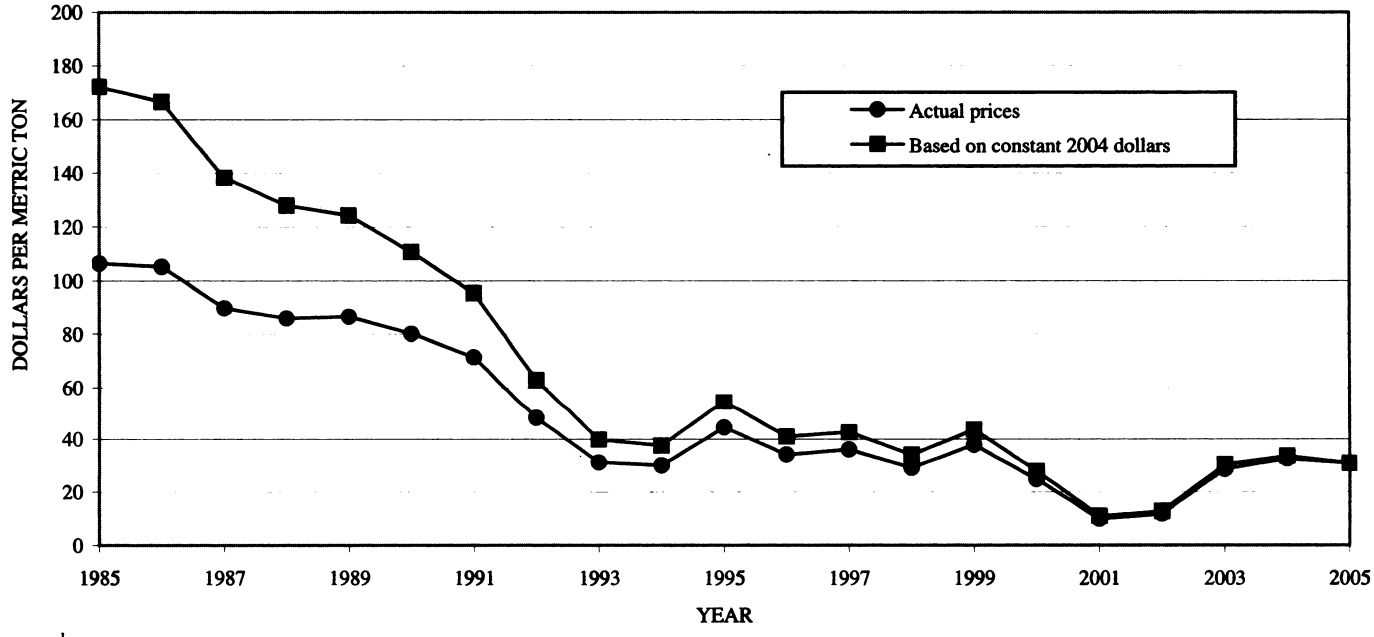
FIGURE 1
TRENDS IN SULFUR PRODUCTION IN THE UNITED STATES



*Includes 10 months of Frasch data for 1993; the other 2 months are included with the recovered sulfur data to avoid disclosing company proprietary data. Data for 1994 through 2000 are estimates.

FIGURE 2
ESTIMATED AVERAGE PRICE OF SULFUR IN ACTUAL AND CONSTANT DOLLARS[1]



[1]Based on the reported average value for elemental sulfur (Frasch and recovered), free on board mine and/or plant.

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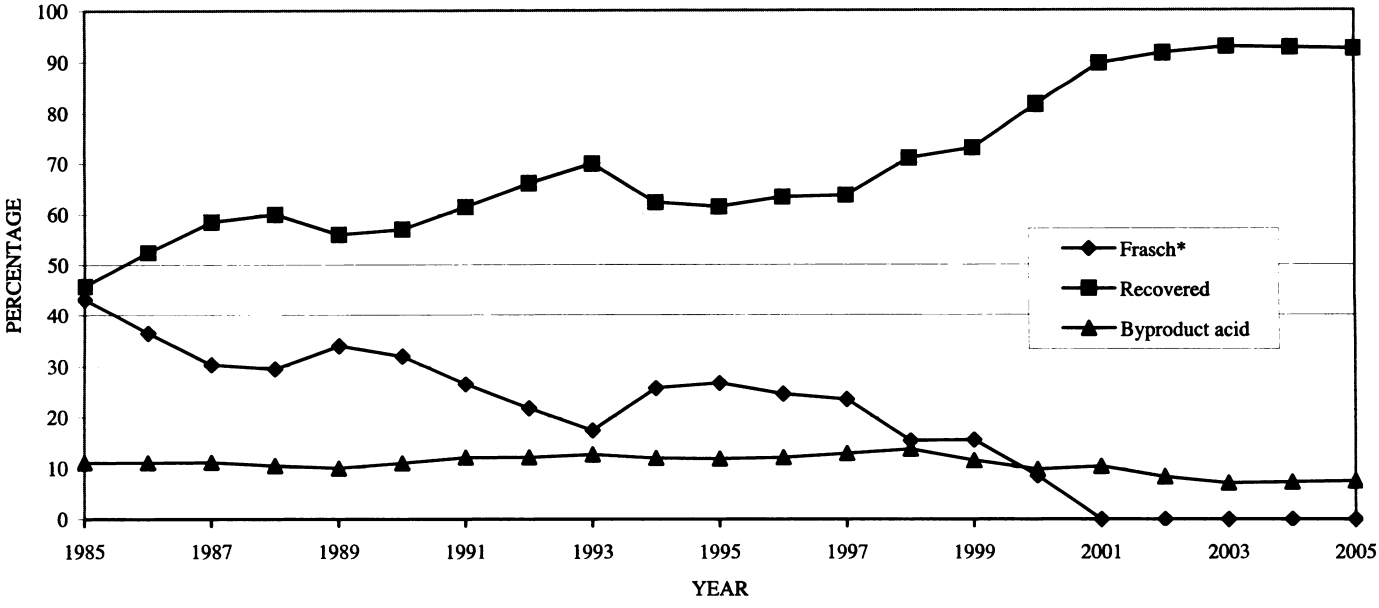
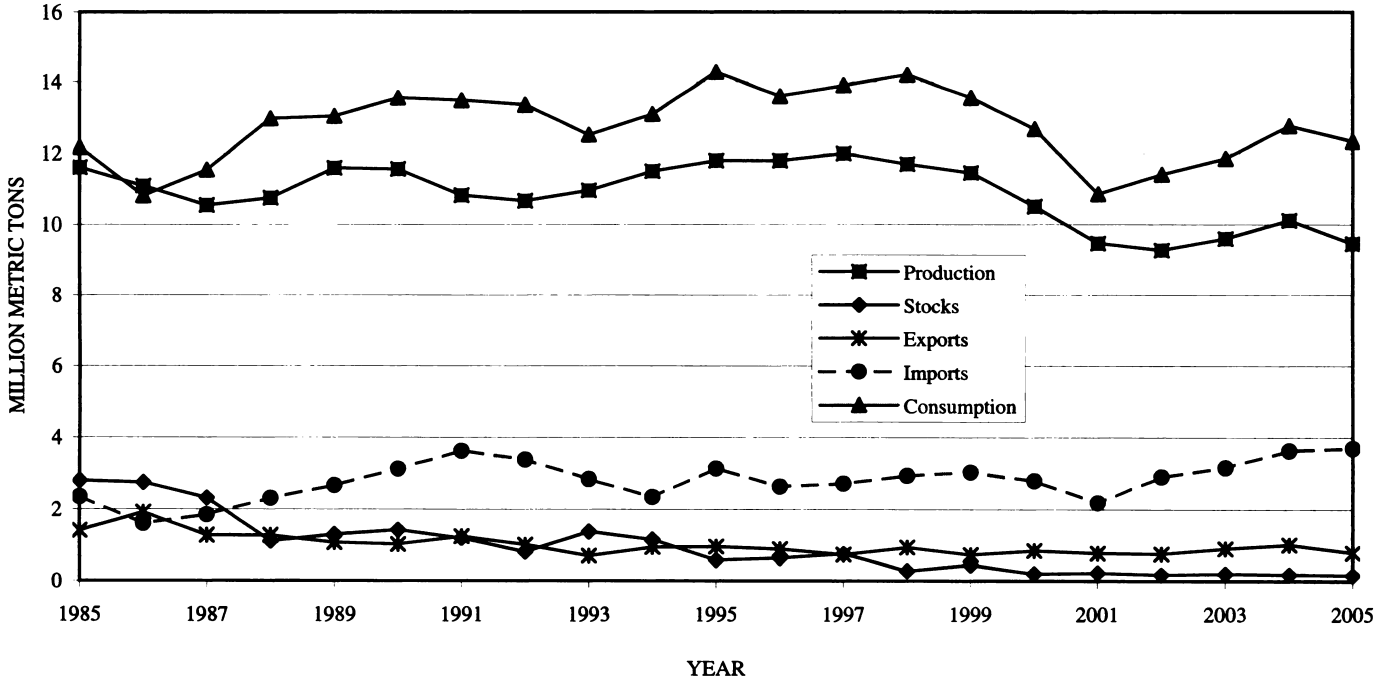
FIGURE 3
PERCENTAGE OF SULFUR PRODUCTION BY SOURCE



*Includes 10 months of Frasch data for 1993; the other 2 months are included with the recovered sulfur data to avoid disclosing company proprietary data. Data for 1994 through 2000 are estimates.

FIGURE 4
TRENDS IN SALIENT SULFUR STATISTICS



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TALC AND PYROPHYLLITE

By Robert L. Virta

Domestic survey data and tables were prepared by Raymond I. Eldridge III, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

In 2005, production of talc increased to 856,000 metric tons (t) valued at $24.4 million from 833,000 t valued at $23.2 million in 2004 (table 1). Domestic sales decreased to 826,000 t valued at $71.3 million from 854,000 t valued at $74.8 million in 2004. Exports decreased slightly to 198,000 t in 2005 from 202,000 t in 2004. Imports increased to 237,000 t in 2005 from an estimated 226,000 t in 2004. U.S. apparent consumption increased to 895,000 t in 2005 compared with 857,000 t in 2004. World production of talc and pyrophyllite was 8.25 million metric tons (Mt) in 2005 compared with 8.23 Mt in 2004. U.S. production and sales of pyrophyllite decreased in 2005 compared with 2004; data are withheld to avoid disclosing company proprietary data.

The mineral talc is a hydrous magnesium silicate. A massive talcose rock is called steatite, and an impure massive variety is known as soapstone. Talc is used commercially because of its fragrance retention, luster, purity, softness, and whiteness. Other commercially important properties of talc are its chemical inertness, high-dielectric strength, high-thermal conductivity, low electrical conductivity, and oil and grease adsorption. The major markets for talc are ceramics, paint, paper, and plastics.

Pyrophyllite is a hydrous aluminum silicate with a structure similar to talc. Such properties as chemical inertness, high dielectric strength, high melting point, and low electrical conductivity make it useful for ceramic and refractory applications.

Legislation and Government Programs

In 2005, the U.S. Department of Defense authorized the disposal of 867 t of block and lump talc and 1,050 t of ground talc, which was the entire uncommitted inventory, from the National Defense Stockpile.

Production

Talc.—Domestic production data were obtained through a voluntary survey of U.S. mining companies conducted by the U. S. Geological Survey (USGS). Survey forms were sent to 10 companies that mined talc. Responses were received from four companies, and two other companies did not mine talc in 2005. Data for nonrespondents were estimated from preliminary reported data based on 9 months of production in 2005, reported prior-year data adjusted according to employment and consuming industry trends, and data obtained from associated milling operations. Responses accounted for about 76% of the production data presented in table 1.

In 2005, 8 companies operating 10 mines in 6 States mined soapstone, steatite, and talc. All were open pit mining operations. The producers, in decreasing order of production, were Luzenac America Inc.; Wold Talc Co.; Barrett's Minerals Inc. (a subsidiary of Minerals Technologies Inc.); Gouverneur Talc Co.; Milwhite Inc.; Suzorite Mineral Products Inc. (a subsidiary of Zemex Corp); New World Stone Co., and Steatite of Southern Oregon. CalTalc Co. did not mine in 2005 but worked from stockpiles. The four leading domestic producers collectively accounted for more than 75% of the U.S. tonnage mined.

In 2005, U.S. mine production increased to 856,000 t valued at $24.4 million compared with 833,000 t valued at $23.2 million in 2004 (table 1). Production increased slightly in Montana, Vermont, and Virginia and decreased slightly in California, New York, and Texas. Production in Oregon was almost unchanged from 2004. Montana led all States in the tonnage of talc produced, followed by Texas, Vermont, New York, Virginia, and Oregon. Mines operating in Montana, New York, Texas, and Vermont accounted for nearly all domestic talc production.

Pyrophyllite.—Domestic production data were acquired through a voluntary USGS survey of the three U.S. companies that mined pyrophyllite. Two companies responded to the survey; the remaining data were estimated from reported prior-year data adjusted according to employment data and consuming industry trends. Data are withheld to avoid disclosing company proprietary data.

Piedmont Minerals Co. Inc. and Standard Mineral Co. Inc. operated three mines in North Carolina. Production of pyrophyllite decreased slightly from that of 2004.

Consumption

Domestic consumption data for talc and pyrophyllite were developed by the USGS from a voluntary survey of U.S. mills. Survey forms were sent to 11 companies operating 13 mills in 7 States for talc and 2 companies operating 2 mills in 1 State for pyrophyllite. Responses accounted for 78% of the talc data presented in table 2. The remaining data were estimated from preliminary reported data based on 9 months of production in 2005 and reported prior-year data adjusted according to employment and consuming industry trends. Both pyrophyllite producers responded.

Talc.—Sales and use were 826,000 t of talc valued at $71.3 million in 2005, a decrease from 854,000 t valued at $74.8 million in 2004 (table 1). Domestic sales by U.S. producers decreased to 693,000 t in 2005 from 712,000 t in 2004. Talc was sold domestically for ceramics (sanitaryware and tiles), paint, paper, other (unspecified) applications, roofing, plastics, rubber, cosmetics, and refractory products, in decreasing order of consumption (table 2).

Sales of talc to manufacturers of paint, roofing, and tile generally are tied to the housing industry. Construction starts for new privately owned housing increased to 2.06 million units in 2005 from 1.96 million units in 2004 (U.S. Census

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Bureau, 2006b§[1]). The value of all construction (residential and commercial) increased to $1.12 trillion in 2005 from $1.03 trillion in 2004 (U.S. Census Bureau, 2006a§).

Shipments of architectural paint (the major paint market for talc) increased to 3.25 billion liters (858 million gallons) in 2005 from 3.06 billion liters (809 million gallons) in 2004 (U.S. Census Bureau, 2006). Ceramic tile is a major market for talc, and U.S. producers must sell their talc to tile producers that compete with imported ceramic tile. The U.S. International Trade Commission reported that imports of ceramic tile under Harmonized Tariff Schedule of the United States codes 6907.10.00, 6908.10.10, 6908.10.20, and 6908.10.50 increased to 31.5 million square meters valued at $218 million in 2005 from 29.2 million square meters valued at $198 million in 2004 (U.S. International Trade Commission, 2006§).

Most of the 237,000 t of imported talc listed in table 5 was not included in the domestic end-use data listed in table 2. An estimated end-use breakdown of sales of imports in 2005 is plastics, 98,000 t; cosmetics, 40,000 t; paint, 39,000 t; unknown, 25,000 t; ceramics and refractory products, 17,000 t; paper, 12,000 t; and rubber, 6,000 t.

Pyrophyllite.—In 2005, domestic consumption of pyrophyllite decreased from that of 2004; data are withheld to avoid disclosing company proprietary data. Pyrophyllite was used in ceramics, refractory products, paint, and unspecified applications, in decreasing order of consumption. Ceramic and refractory uses accounted for more than 50% of domestic pyrophyllite sales. The largest decline was in sales for refractory products.

Prices

The unit value of crude talc was estimated to be $29 per metric ton. Most of the talc sold in the United States was sold only after crushing and grinding. Following sorting to remove waste, primary crushing, and screening, the unit value of the unmilled talc probably would be in the range of $50 to $60 per ton at the mill. The average reported unit value of processed talc was $86 per ton in 2005, a slight decrease from $88 per ton in 2004. The decline in unit value probably does not include energy surcharges that have become customary in the past couple of years. The average unit value of crude pyrophyllite was essentially unchanged from that of 2004 while that of processed pyrophyllite increased slightly.

The average free alongside ship unit value for exports of unmilled talc increased to $251 per ton in 2005 from $207 per ton in 2004. The large unit values in 2004 and 2005 probably reflect the inclusion of shipments of milled talc products, surface-treated talc, sculpting-grade talc, and possibly finished products, such as body powders under this U.S. Census Bureau Schedule B export code. The unit value for milled talc exports increased to $208 per ton in 2005 from $196 per ton in 2004. The unit value of all exports increased to $211 per ton in 2005 from $196 per ton in 2004.

The average customs unit value for imports of unground talc was $148 per ton in 2005, an increase from $127 per ton in 2004. The average customs value for ground talc was $175 per ton in 2005, a decline from $293 per ton in 2004. The difference in unit values between 2004 and 2005 for this import code reflects the inclusion of several low-tonnage, high-value shipments that exceeded $2,000 per ton (probably representing packaged talc products) in 2004. The average customs value for cut or sawed talc was $874 per ton, essentially unchanged from 2004. The unit value for all talc imports was $235 per ton in 2005 compared with $258 per ton in 2004.

Prices for talc ranged from $101 to $403 per ton (table 3). Prices for pyrophyllite from the Republic of Korea, free on board port, were $59 to $65 per ton for fiber glass and refractory manufacturing, $27 to $44 per ton for ceramic grade, and $110 to $115 per ton for filler grade. The price for filler grades from Australia was $342 per ton (Industrial Minerals, 2005). Quoted prices should be used only as a guideline because actual prices depend on the terms of the contract between seller and buyer.

Foreign Trade

Talc exports decreased in tonnage to 198,000 t valued at $41.8 million in 2005 from 202,000 t valued at $39.6 million in 2004. Canada was the leading importer of talc from the United States, followed by Mexico and Belgium (table 4). Much of the talc exported to Mexico was shipped to U.S. affiliates operating across the Mexican border and was not reported by the U.S. Census Bureau. Total talc exported to Mexico in 2005, including shipments to U.S. affiliates, exceeded 50,000 t.

Talc imports reported by the U.S. Census Bureau increased in tonnage to 237,000 t valued at $55.6 million in 2005 from 226,000 t valued at $58.4 million in 2004. China was the leading source for imported talc, followed by Canada (table 5).

World Industry Structure

World production of talc and pyrophyllite was estimated to be 8.25 Mt in 2005, almost unchanged from 8.23 Mt in 2004. China was the world's leading producer of talc, followed by the United States, India, Brazil (crude), and France (crude). The Republic of Korea was the leading producer of pyrophyllite, followed by Japan and Brazil. Brazil, China, France, India, Japan, the Republic of Korea, and the United States produced 85% of the world's talc and pyrophyllite (table 6).

World Review

France.—Rio Tinto plc announced a reorganization of its industrial minerals businesses. Luzenac Group, which has talc mines and mills on four continents, Rio Tinto Borax, and Dampier Salt Ltd., were placed under a common management and will operate as Rio Tinto Minerals. The action was taken to improve efficiencies of operation (Rio Tinto plc, 2005).

Outlook

Based on current trends, U.S. mining and sales of talc probably will remain relatively steady for the next few years. Talc imports increased dramatically between 1985 and 2000 but have leveled off in the past few years. China was the major source of the

[1]References that include a section mark (§) are found in the Internet References Cited section.

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increasing talc imports in the 1990s and is still the leading source of talc imports in 2005. With the continuing construction boom for residential and commercial buildings, sales of talc for such construction-related applications as adhesives, ceramics, joint compounds, paint, and roofing applications are expected to remain strong. The quantity of talc used in plastics is expected to increase as the volume of plastics used in consumer products increases and as manufacturers attempt to reduce costs associated with rising energy and resin prices. No major changes are expected in the pyrophyllite markets in the near future.

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TABLE 1
SALIENT TALC AND PYROPHYLLITE STATISTICS[1]

(Thousand metric tons and thousand dollars)

	2001	2002	2003	2004	2005
United States:					
Mine production, crude:					
Quantity:					
Talc	863	828	840	833 r	856
Pyrophyllite	W	W	W	W	W
Value:					
Talc	19,500	22,200	22,700	23,200 r	24,400
Pyrophyllite	W	W	W	W	W
Sold by producers, crude and processed:					
Quantity:					
Talc	784	764	845	854 r	826
Pyrophyllite	W	W	W	W	W
Value:					
Talc	84,800	75,000	75,200	74,800 r	71,300
Pyrophyllite	W	W	W	W	W
Exports, talc[2]					
Quantity:	137	166	192	202	198
Value:	28,800	35,700	39,100	39,600	41,800
Imports for consumption					
Quantity:	180	232	237	226	237
Value:	35,800	52,700	53,500	58,400	55,600
Apparent consumption[3]	906	894	885	857 r	895
World, production	8,780 r	7,590 r	8,100 r	8,230 r	8,250 e

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Excludes powders-talcum (in package), face, and compact.

[3]Production plus imports minus exports plus adjustments in Government and industry stock. Does not include pyrophyllite.

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TABLE 2
END USES FOR GROUND TALC[1]

(Thousand metric tons)

	2004	2005
Ceramics[2]	227 r	220
Cosmetics	8 r	8
Insecticides	--	--
Paint	147 r	139
Paper	114 r	114
Plastics	34 r	36
Refractories	--	1
Roofing	63 r	58
Rubber	24 r	21
Other[3]	95 r	95
Total	712 r	693

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes tile.

[3]Includes art sculpture, asphalt filler, auto body filler, construction caulks, flooring, joint compounds, and other uses not specified.

TABLE 3
PRICES OF TALC

(Dollars per metric ton)

	Price
New York:	
Paint:	
200 mesh	139
400 mesh	231
Ceramic:	
200 mesh	101
325 mesh	127
Indian, cosmetic-grade	190-195
Chinese, normal (ex-store UK):	
200 mesh	358-401
350 mesh	368-403

Source: Industrial Minerals, December 2005.

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TABLE 4
U.S. EXPORTS OF TALC[1, 2]

(Thousand metric tons and thousand dollars)

Country	2004		2005	
	Quantity	Value[3]	Quantity	Value[3]
Belgium	9	1,930	10	2,250
Canada[4]	102	14,000	94	14,200
Germany	4	1,120	3	889
Japan	7	1,510	6	1,390
Mexico	17	2,750	21	5,090
Singapore	5	1,460	2	750
Other[5]	58	16,800	62	17,300
Total	202	39,600	198	41,800

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Excludes powders-talcum (in package), face, and compact.
[3]Free alongside ship.
[4]Probably includes shipments in transit through Canadian ports.
[5]Includes 66 countries in 2004 and 65 countries in 2005.

Source: U.S. Census Bureau.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF TALC, BY COUNTRY[1]

Country	Not crushed or powdered		Crushed or powdered		Cut and sawed		Total unmanufactured	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
2004:								
Brazil	28	$11	68	$14	755	$764	847	$789
Canada	8	7	66,700	18,400	17,500	13,600	84,200	32,000
China	119,000	15,500	1,440	447	2,030	1,900	123,000	17,900
France	--	--	1,120	1,100	1,460	1,650	2,580	2,750
Japan	--	--	5,670	830	55	89	5,730	919
Other[2]	6,070	528	2,400	1,990	687	1,610	9,160	4,130
Total	126,000	16,000	77,400	22,700	22,500	19,700	226,000	58,400
2005:								
Brazil	91	45	67	17	931	939	1,090	1,000
Canada	27	31	55,800	17,200	20,300	16,200	76,200	33,400
China	95,200	13,900	1,150	374	1,160	1,190	97,500	15,500
France	19	10	17,400	1,340	536	699	17,900	2,050
Japan	--	--	15,100	809	32	70	15,200	879
Other[2]	127	84	28,000	885	807	1,750	28,900	2,720
Total	95,500	14,100	118,000	20,700	23,800	20,800	237,000	55,600

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes 27 countries in 2004 and 26 countries in 2005.

Source: U.S. Census Bureau.

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TABLE 6

TALC AND PYROPHYLLITE: WORLD PRODUCTION, BY COUNTRY AND PRODUCT[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Argentina:					
Pyrophyllite	2,155	1,770	1,894	2,178 [r]	2,200
Steatite[e]	300	300	300	300	300
Talc	1,665	1,643	1,700 [r]	7,620 [r]	7,600
Australia:[4]					
Pyrophyllite[e]	1,500	868 [5]	1,000	1,000	1,200
Talc	173,446	173,741	174,000 [e]	173,000 [e]	170,000
Austria, soapstone and talc, crude	137,776 [r]	138,195 [r]	137,596 [r]	138,000 [r, e]	138,000
Bhutan, talc[e]	3,800	3,900	3,900	3,900	4,000
Brazil:					
Pyrophyllite, crude	189,500	200,000	200,000 [e]	200,000 [e]	200,000
Talc:					
Crude	397,000	348,000	369,000 [r]	400,975 [r]	401,000
Marketable product[6]	6,300	5,617	5,593	5,600 [e]	6,000
Canada, pyrophyllite, soapstone, talc[e]	90,000 [5]	90,000	90,000	90,000	90,000
Chile, talc	4,177	3,537	4,374	2,993 [r]	3,000
China, unspecified[e]	3,500,000	2,500,000	3,000,000	3,000,000	3,000,000
Colombia, pyrophyllite, soapstone, talc[e]	15,000	15,000	15,000	15,000	15,000
Egypt, pyrophyllite, soapstone, steatite, talc[e]	40,000	40,000	40,000	40,000	40,000
France, talc, crude[e]	350,000	350,000	350,000	350,000	350,000
Germany, steatite and talc, marketable[e]	7,000 [r]	7,000 [r]	7,000 [r]	7,000 [r]	6,000
Guatemala, talc	--	568	1,585	2,863	2,900
Hungary, talc[e]	500	500	500	500	500
India:[e]					
Pyrophyllite	86,000	85,000	86,000	86,000	85,000
Steatite	546,000	550,000	552,000	550,000	545,000
Iran, talc[7]	60,282 [r]	68,007 [r]	65,833 [r]	187,465 [r]	190,000
Italy, steatite and talc[e]	140,000	140,000	140,000	140,000	140,000
Japan:					
Pyrophyllite	403,137 [r]	416,188 [r]	408,435 [r]	401,688 [r]	410,000
Talc	18,478 [r]	22,142 [r]	24,328 [r]	18,253 [r]	21,000
Korea, North, unspecified[e]	60,000 [r]	50,000 [r]	50,000 [r]	50,000 [r]	50,000
Korea, Republic of:					
Pyrophyllite	1,101,825	889,961	912,285	827,895 [r]	820,000
Talc	47,712	37,863	47,911	79,313 [r]	79,500
Macedonia, talc	557	550	550	600 [e]	600
Mexico, talc	77,650	111,621	114,870	101,896 [r]	100,000
Morocco	27,246	39,612	1,959	2,000 [e]	2,000
Nepal, talc[8]	3,923	2,621	6,905 [r]	3,435 [r]	3,600
Norway, soapstone, steatite, talc[e]	27,000	28,000	28,000	28,000	29,000
Pakistan, pyrophyllite[e]	55,000	57,500 [5]	55,000	55,000	57,500
Paraguay, pyrophyllite, soapstone, talc[e]	200	200	200	200	200
Peru:					
Pyrophyllite[e]	8,000	8,000	12,296 [5]	14,282 [r, 5]	14,500
Talc	11,165	10,685	10,791	9,548 [r]	10,000
Portugal, talc[e]	8,200	8,200	8,200	8,000	8,000
Romania, talc	7,270	7,292	10,082	10,000 [e]	10,000
Russia, talc[e]	100,000	100,000	100,000	100,000	100,000
Slovakia, talc	2,600	2,290	1,000	1,500 [e]	1,500
South Africa:					
Pyrophyllite	14,047 [r]	15,587	14,350 [r]	35,152 [r]	55,278 [5]
Talc	3,030 [r]	2,511	6,719 [r]	8,115 [r]	8,469 [5]
Spain, steatite and talc[e]	100,000	100,000	100,000	100,000	100,000
Sweden, soapstone and talc	15,000	15,000	15,000	14,000 [e]	14,000

See footnotes at end of table.

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TABLE 6—Continued

TALC AND PYROPHYLLITE: WORLD PRODUCTION, BY COUNTRY AND PRODUCT[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Taiwan, talc	130	27	466	411	-- [5]
Thailand:					
Pyrophyllite	59,602	103,496	73,556	108,691 [r]	85,000
Talc	6,838	1,702	8,501	12,592 [r]	9,500
Turkey	883	98	60 [r]	60 [r, e]	100
Uganda, soapstone	--	-- [r]	-- [r]	-- [r]	--
United Kingdom, pyrophyllite, soapstone, talc[e]	5,000	5,000	5,000	5,000	5,000
United States:					
Pyrophyllite	W	W	W	W	W
Talc	863,000	828,000	840,000	833,000 [r]	856,000 [5]
Uruguay, pyrophyllite, soapstone, talc	1,694	816 [r]	1,095 [r]	1,042 [r]	1,100
Zimbabwe, talc	1,273	911	196	--	--
Grand total	8,780,000 [r]	7,590,000 [r]	8,100,000 [r]	8,230,000 [r]	8,250,000
Of which:					
Pyrophyllite	1,920,000 [r]	1,780,000 [r]	1,760,000 [r]	1,730,000 [r]	1,730,000
Steatite	546,000	550,000	552,000	550,000	545,000
Talc	2,150,000 [r]	2,090,000 [r]	2,160,000 [r]	2,320,000 [r]	2,340,000
Unspecified	4,170,000 [r]	3,170,000 [r]	3,630,000 [r]	3,630,000 [r]	3,630,000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total." -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through April 19, 2006.

[3]In addition to the countries listed, Nigeria may produce talc, but information is inadequate to estimate output.

[4]Data based on fiscal year ending June 30 of year stated.

[5]Reported figure.

[6]Direct sales and/or beneficiated (marketable product).

[7]Data based on fiscal year beginning March 21 of year stated.

[8]Data based on fiscal year beginning mid-July of year stated.

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THORIUM

By James B. Hedrick

Domestic survey data and table were prepared by Nicolas A. Muniz, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Thorium demand worldwide is relatively small. There was no domestic production of thorium in 2005. All thorium compounds, metal, and alloys used by the domestic industry were derived from imports, company stocks, or material previously acquired from the U.S. Government stockpile. Domestic imports for consumption of refined thorium products decreased by 7% in 2005 according to data collected by the U.S. International Trade Commission (USITC) (table 1). The value of thorium metal and compounds used by the domestic industry in 2005 was estimated to be about $145,000, a decrease from $170,000 in 2004. Only minor amounts, less than 10 metric tons (t), of thorium are used annually. However, large fluctuations in demand are caused by intermittent use, especially for catalytic applications that do not require annual replenishment.

Thorium and its compounds were produced primarily from the mineral monazite, which was recovered as a byproduct of processing heavy-mineral sands for titanium, zirconium, or tin minerals. Monazite was recovered primarily for its rare-earth content, and only a small fraction of the byproduct thorium produced was consumed. Monazite-producing countries were Brazil, India, Malaysia, and Sri Lanka.

Problems associated with thorium's natural radioactivity represented a significant cost to those companies involved in its mining, processing, manufacture, and use. The costs to comply with environmental regulations, potential legal liabilities, and the excessive costs to purchase storage and waste disposal space were the principal deterrents to its commercial use. Health concerns associated with thorium's natural radioactivity have not been a significant factor in switching to alternative nonradioactive materials (Ed Loughlin, Grace-Davison division of W.R. Grace & Co., oral commun., 1997; Don Whitesell, The Coleman Company, Inc., oral commun., 2002).

Limited demand for thorium, compared with that for rare earths continued to create a worldwide oversupply of thorium compounds and residues. Most major rare-earth processors have switched feed materials to thorium-free intermediate compounds, such as rare-earth chlorides, hydroxides, or nitrates. Excess thorium not designated for commercial use was either disposed of as a low-level radioactive waste or stored for potential use as a nuclear fuel or in other applications. Principal nonenergy uses have shifted from refractory applications to chemical catalysts, lighting, and welding electrodes.

Legislation and Government Programs

The Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 authorized the National Defense Stockpile (NDS) manager to obligate up to $59.7 million from the NDS Transaction Fund for authorized uses under the Strategic and Critical Materials Stock Piling Act (50 U.S.C. 98h), including disposal of hazardous materials that are environmentally sensitive, which includes thorium nitrate. Fiscal year 2005 funding decreased by $10 million from that of the previous fiscal year. The Annual Materials Plan for fiscal year 2005, released February 1, 2005, authorized the disposal of all 3,218,697 kilograms (kg) (7,100,000 pounds) of thorium nitrate classified as excess to goal from the NDS.

Based on the funding appropriated by Congress, studies were conducted in 2003 on the disposal of thorium nitrate in the NDS. As required under the National Environmental Policy Act (42 U.S.C. 4321 et seq.), an environmental assessment was prepared to evaluate the potential environmental impacts associated with proposed action to transfer the DNSC's thorium nitrate to the Nevada Test Site (NTS) for disposal. The thorium nitrate is stored at DNSC depots at Curtis Bay, MD, and Hammond, IN. Approximately 21,000 drums containing thorium nitrate and 10 drums containing converted thorium nitrate were loaded into cargo containers and transported to the NTS where the cargo containers were placed in disposal cells. The DNSC began the disposal of the entire NDS stockpile of thorium nitrate from its depots in Maryland and Indiana to the NTS, which is about 105 kilometers (65 miles) northwest of Las Vegas, NV. Shipments of thorium nitrate began from the Curtis Bay NDS depot in 2004. Shipments of the stockpile at the Hammond NDS depot began in mid-2005. Shipments to Nevada from both depots were completed by the end of fiscal year 2005.

Researchers at General Atomics, The University of Texas, and Thorium Power Inc. began development of a concept design for a new high-temperature, helium-cooled thorium-fueled nuclear reactor based on an existing high-temperature, gas-cooled reactor design developed by General Atomics. The development of the new design (designated HT3R for High-Temperature, Teaching, and Test Reactor) would be directed by the lead group at The University of Texas of the Permian Basin. Funding and research will be provided by General Atomics, The University of Texas-Arlington, The University of Texas-Austin, The University of Texas-Dallas, and The University of Texas of the Permian Basin; additional backing will be provided by Midland Development Corp., Novastar Resources Ltd., Odessa Development Corp., Thorium Power, Inc., the city of Andrews, TX, and Andrews County, TX. The reactor is planned to be built in Andrews (Lobenz, 2006).

In an effort to dispose of excess weapons-grade plutonium produced by the United States and Russia, the U.S. Department of Energy's National Nuclear Security Administration (NNSA) was funded by Congress with $2.8 billion, most of which was awarded to Areva (a consortium owned by the French Government) to use metal oxide (MOX) nuclear fuel technology to dispose of the excess plutonium. As of the last quarter of 2005, no Russian material had been disposed of and less than

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one nuclear warhead's worth of plutonium was "burned-up" in the MOX fuel cycle. The NNSA estimated that an additional $7.4 billion would be needed to complete the project.

An alternative method to dispose of the plutonium is to use a thorium-fueled reactor. A study funded by the NNSA in 2004 was awarded to the Kurchatov Institute in Russia. The cost savings of using the thorium-fuel cycle compared with the MOX technology was estimated to be $5 billion to $7 billion. Westinghouse Electric Company LLC, an independent contractor of the NNSA, assessed the thorium-fuel research at the Kurchatov Institute and verified their results. Westinghouse confirmed the Kurchatov Institute's findings that significant cost savings could be achieved by using the thorium-fuel cycle to generate power and "burn-up" the excess weapons-grade plutonium (Weekly Global Report, 2005§[1]). The NNSA, however, disputed Westinghouse's findings and found that the technology for the thorium fuel approach proposed by the Kurchatov Institute was not ready for deployment and its use would not be practicable before 2018 (Fuel Cycle Week, 2006). Thorium-fuel technology had been used effectively in a commercial reactor at Fort St. Vrain, CO, and problems reported at the site related to the reactor design, not the thorium fuel.

The Oak Ridge National Laboratory monitored the Kurchatov Institute's thorium-fuel program. The Kurchatov Institute is implementing the Radkowski thorium plutonium incinerator (RTPI) fuel design in 1,000-megawatt vodo-vodyanoy energetichskyi reaktory [water-water-moderated energetic reactors] (VVER-1000 MW). The retrofit to the Russian-designed VVER-1000 MW reactors, which presently use uranium fuel, will engage a thorium-plutonium fuel cycle that will "burn-up" plutonium converting it to non-weapons-grade plutonium. Westinghouse was providing expertise to review and analyze the Kurchatov Institute's nuclear reactor's technical designs and economic benefits (Westinghouse Electric Company LLC, 2005§).

Production

Domestic mine production data for thorium-bearing minerals were developed by the U.S. Geological Survey from a voluntary canvass of U.S. thorium operations. The one mine to which a canvass form was sent responded. Although thorium was not produced in the United States in 2005, the mine that had previously produced thorium-bearing monazite continued to produce titanium and zirconium minerals and maintained its monazite capacity on standby. Production of monazite in Florida was expected to resume in 2006; Iluka Resources Limited planned to reprocess tailings mainly for the zircon content. Monazite was last produced in the United States in 1994.

Consumption

Statistics on domestic thorium consumption were developed by surveying various processors and manufacturers, evaluating import and export data, and analyzing Government stockpile shipments.

Domestic thorium producers and processors that were surveyed in 2005 reported no consumption of thorium oxide equivalent in 2005. Additional information on domestic consumption was not available (table 1). Essentially all thorium alloys and compounds used by the domestic industry were derived from imports, company stocks, or materials previously sold from the NDS. Domestic companies processed or fabricated various forms of thorium for nonenergy uses, such as chemical catalysts, lighting, and welding electrodes.

Stocks

Government stocks of thorium nitrate in the NDS were about 3,218,697 kg (actual stockpile, 7,096,012 pounds) on December 31, 2004. At yearend 2005, all stocks of thorium nitrate in the NDS were shipped for disposal to the NTS.

Prices

Thorium oxide prices in 2005, as quoted by Rhodia Electronics and Catalysis, Inc.'s U.S. subsidiary, Rhodia, Inc., were unchanged from the previous year (table 1). At yearend, thorium oxide prices delivered, duty paid were $82.50 per kilogram for 99.9% purity and $107.25 per kilogram for 99.99% purity. Thorium nitrate prices from Rhodia were $27.00 per kilogram for mantle-grade material.

Foreign Trade

Exports of thorium compounds from the United States were 737 t valued at $281,000, an increase in quantity from the 731 t in 2004 (table 2). Principal destinations, in order of quantity were Singapore, United Kingdom, Germany, and Paraguay.

U.S. imports of thorium in 2005 were entirely from France and were 4,930 t valued at $145,000, a decrease from the 5,320 t valued at $170,000 in 2004 (table 2). Rhodia Electronics & Catalysis' rare-earth separation plant in La Rochelle remained the principal source of imported thorium compounds for the United States. Most of the thorium is supplied from older stocks that were produced when the plant was processing monazite. The La Rochelle plant currently processes intermediate rare-earth concentrates that have had the thorium removed.

World Review

Thorium demand worldwide remained depressed because of concerns over its naturally occurring radioactivity. Industrial consumers expressed concerns about the potential liabilities, the cost of complying with environmental monitoring and regulations, and the cost of disposal at approved waste burial sites.

Outlook

Thorium use in the United States has decreased substantially during the past decade. Domestic demand is expected to remain at recent depressed levels unless low-cost technology is developed to dispose of thorium residues created as a byproduct

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during mineral processing or thorium's use as a nonproliferative nuclear fuel gains widespread commercialization. In the long term, high-disposal costs, increasingly stringent regulations, and public concerns related to thorium's natural radioactivity are expected to continue to depress its use in nonenergy applications in the United States as well as worldwide.

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TABLE 1
SALIENT U.S. REFINED THORIUM STATISTICS[1]

(Kilograms and dollars per kilogram)

	2001	2002	2003	2004	2005
Exports, gross weight:					
Thorium ore, including monazite	--	--	23,000	18,000 r	--
Compounds	7,300	880	590	731	737
Imports, compounds, gross weight[2]	1,850	650	4,140	5,320	4,930
Prices, yearend:					
Nitrate, gross weight[3]	27.00	27.00	27.00	27.00	27.00
Oxide, 99.9% purity[4]	82.50	82.50	82.50	82.50	82.50

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits, except prices.

[2]Source: U.S. International Trade Commision.

[3]Source: Rhodia Canada, Inc., free on board port of entry, duty paid, thorium oxide basis.

[4]Source: Rhodia Electronics and Catalysis, Inc.

TABLE 2
U.S. FOREIGN TRADE IN THORIUM AND THORIUM-BEARING MATERIALS[1]

(Kilograms and dollars)

	2004		2005		
	Quantity	Value	Quantity	Value	Principal destinations/sources and quantities, 2005
Exports:					
Thorium ore, monazite concentrate	18,000 r	4,710 r	--	--	XX.
Compounds	731	298,000	737	281,000	Singapore 299; United Kingdom 280; Germany 110; Paraguay 29.
Imports, compounds	5,320	170,000	4,930	145,000	France 4,930.

rRevised. XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits.

Source: U.S. Census Bureau.

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TABLE 3

MONAZITE CONCENTRATE: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, gross weight)

Country[3]	2001	2002	2003	2004	2005
Brazil	--	--	--	731 [4]	800 [p]
India	5,000	5,000	5,000	5,000	5,000
Malaysia	643 [4]	441 [4]	795 [4]	1,683 [r, 4]	700
Total	5,640	5,440	5,800	7,410 [r]	6,500

[p]Preliminary. [r]Revised. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through April 18, 2006.

[3]In addition to the countries listed, China, Indonesia, Nigeria, North Korea, the Republic of Korea, and countries of the Commonwealth of Independent States may produce monazite; available general information is inadequate for formulation of reliable estimates of output levels.

[4]Reported figure.

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TIN

By James F. Carlin, Jr.

Domestic survey data and tables were prepared by Elsie D. Isaac, statistical assistant, and the world production tables were prepared by Linder Roberts, international data coordinator.

Tin has not been mined in the United States since 1993; consequently, the country is reliant on imports and recycling for its tin needs. In 2005, twenty-five firms consumed 88% of the reported primary tin used domestically. The major uses were as follows: electrical solders, 26%; metal containers, 20%; transportation, 14%; construction, 11%; and other, 29%. The estimated value of primary tin metal consumed domestically was about $341 million. Industry stocks declined by about 8% compared with those at yearend 2004 (table 1).

Approximately 14,000 metric tons (t) of tin, most of it from old scrap, was recycled (table 5). About one-third of the tin consumed in the United States was recycled metal produced at 2 detinning plants and 91 secondary nonferrous metal processing plants. The recycling rate for steel cans was 63%, compared with 62% in 2004, 56% in 1995, and 15% in 1988 (Steel Recycling Institute, 2006).

The Defense Logistics Agency (DLA), which manages the National Defense Stockpile (NDS), sold 10,800 t of pig tin from the stockpile during 2005. World primary tin mine output declined about 2% from that in 2004 (tables 1, 9). Industry observers considered the world tin market in 2005 to be in slight oversupply. World primary tin smelter production rose by about 11% compared with that of 2004. The composite tin price declined by 12% from that of 2004. The price decline was attributed to the slight world supply excess. Of the 21 countries in which tin was mined, the top 5 accounted for 94% of the world total of 292,000 t. China was the leading producer (41% of world output) and was followed by Indonesia (27%), Peru (14%), Bolivia (6%), and Brazil (4%). World tin reserves were estimated to be 6.1 million metric tons (Mt). Assuming that world primary tin consumption to be about 350,000 metric tons per year (t/yr), these reserves would last 17 years. Most tin reserves are in Asia and South America.

In Alaska, Solomon Resources Ltd. and Brett Resources Ltd., both based in Vancouver, British Columbia, Canada, signed a letter of intent to grant Brett an option on Solomon's 100%-owned Sleitat Mountain tin-silver-tungsten deposit, located in the Taylor Mountains quadrangle in southwestern Alaska. The Sleitat Mountain Project covers 1,425 hectares (3,500 acres) located about 135 kilometers northeast of the coastal town of Dillingham, AK. The deposit outcrops on Sleitat Mountain, where tin, tungsten, and silver mineralization occur in an east-west trending, steeply dipping zone that extends at least 975 meters along the trend (TIN World, 2006).

Legislation and Government Programs

In 2005, the DLA sold 8,364 t of tin under the basic ordering agreement (BOA) and the long-term negotiated contract formats. The effect of proposed NDS tin sales on domestic markets is assessed by the Market Impact Committee comprised of several Federal agencies, including the U.S. Geological Survey (USGS).

The DLA Annual Materials Plan proposed amount of material to sell is 12,000 t per fiscal year. The remaining inventory is stored at the Hammond, IN, depot. The Defense National Stockpile Center (DNSC) expects the inventory to be exhausted by the end of fiscal year 2007 through BOA sales. Under the BOA approach, DNSC posts the amount of tin it wants to sell on its Web site every Tuesday. Interested and qualified companies submit quotes and DNSC makes a determination to award by the end of that business day.

Production

Mine.—Tin was not produced at any domestic mine in 2005. Until 1993, a few small tin mines had operated sporadically in the United States. However, the USGS canvasses confirm that there has been no primary domestic tin production since that year.

Secondary.—Industry analysts considered the United States to be the world's leading producer of secondary tin. Most secondary tin has been produced in the United States from various scrapped alloys of tin and recycled in those same alloy industries. Secondary tin from recycled fabricated parts has been used in many kinds of products and is a particularly important source of tin for the manufacture of solder and brass/bronze.

The Steel Recycling Institute, funded by the domestic steel industry, continues to promote the collection, preparation, and transportation of steel can scrap. The domestic recycling rate for steel cans, most of which are made from tinplate, was 63% in 2005, up slightly from 62% in 2004 (Steel Recycling Institute, 2006).

Consumption

In 2005, consumption of primary tin decreased by 12% (tables 1, 2). Domestic consumption data for tin were developed by the USGS from a voluntary survey of tin consumers. Of the 156 firms to which a survey form was sent, 100 responded, including the major consumers.

The total number of metal cans shipped was 133 billion in 2005 compared with 135 billion in 2004. The Can Manufacturer's Institute no longer provides a categorization by types of can (for example, aluminum versus steel). Steel (essentially tinplate and tin-free steel) dominated in the food, pet, and the "general line" can markets, and aluminum held 100% of the beverage can market (Can Manufacturer's Institute, 2005).

The consolidation of the domestic steel industry continued, but at a slower rate than in recent years. There was one major acquisition—Mittal Steel Co. NV (Rotterdam, Netherlands),

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owner of Mittal Steel USA, acquired the International Steel Group (ISG) (Cleveland, OH) for $4.5 billion. ISG was comprised of a series of major domestic steel producers who had entered into bankruptcy, such as Acme Steel Corp., Bethlehem Steel Corp., LTV Steel Corp., and Weirton Steel Corp. ISG was the second-ranked integrated steel producer in the United States behind U.S. Steel Corp., with a capacity of 23 Mt. Mittal's purchase of ISG made it the world's leading steel and tinplate producer. Mittal's tinplate production which includes production sites in Algeria, Kazakhstan, South Africa, and the United States, has capacity of 2.5 million metric tons per year (Mt/yr) of tinplate.

Price

The Platts Metals Week average composite price for tin metal declined by 12% compared with that of 2004. The Platts Metals Week average composite price was $5.04 per pound in January and rose to $5.44 per pound in March. It declined fairly steadily to finish December at $4.43 per pound. Industry analysts attributed the price decline to a moderate-size global excess supply of tin.

The London Metal Exchange (LME) remained the primary trading site for tin. Tin is one of only six metals traded on the LME. The other metals are aluminum, copper, lead, nickel, and zinc.

Trade

U.S. imports of refined tin, which supplied most domestic tin requirements, decreased by 21% compared with those of 2004. Imports of tin in all forms (metal, ore and concentrate, scrap, and waste) remained duty free (tables 7, 8). The tin was imported from many countries and was held in U.S. warehouses by trading firms until sold to customers. Foreign-owned trading firms tended to dominate the marketing of imports. United States imports of refined tin came mostly from Peru, Bolivia, Indonesia, China, and Brazil, in descending order. Refined tin exports were small compared with imports (table 6).

World Review

Argentina.—Silver Standard Resources Inc. (Vancouver) announced plans to restart the Pirquitas silver and tin project in Argentina. The company aimed to update the project's 1999-2000 feasibility study and expected to invest $100 million in the restart. The feasibility study was expected to be completed by 2006. The previous feasibility study, carried out by Sunshine Mining Co. (Kellogg, ID) projected production of 343,000 kilograms per year (kg/yr) of silver and 3,000 metric tons per year (t/yr) of tin during an 8-year mine life (CRU Week in the News, 2005g§[1]).

Australia.—Bluestone Tin Ltd. (Perth) became a member of the International Tin Research Institute (ITRI) (Frogmore, United Kingdom). ITRI does research work on behalf of the global tin industry. By becoming a member, Bluestone (the owner of the Renison Bell Tin Mine on its land in Tasmania) also became a member of the ITRI's sister organization, Tin Technology. ITRI membership now includes most major producers and represents about 70% of global tin production (Platts Metals Week, 2005a).

Bluestone commissioned the 3,500-t/yr Collingwood tin mine in Queensland and expected to make its first shipment of concentrates to Malaysia Smelting Corp. (Butterworth, Malaysia) in January 2006 (CRU Week in the News, 2005h§).

Van Dieman Mines Plc (Sydney) announced plans to establish tin mining operations in Tasmania, Australia, by the end of 2005. Initially, attention was focused on the Scotia and Endurance projects, but the firm has applied to develop other tenents in the area. The firm planned an initial tin production capacity of 1,700 t/yr. Van Dieman owns the right to 13 exploration and retention licences in Tasmania. Historically, records show that the island of Tasmania produced a total of more than 40,000 t of tin from its alluvial operations (CRU Week in the News, 2005c§).

Van Dieman signed an agreement to supply Thailand Smelting and Refining Co. Ltd. (Thaisarco) (Phuket, Thailand) with its entire tin concentrate output. The 6-year contract with Thaisacro is based on the LME tin price at the time of the delivery of the concentrate. At current tin prices, the total value of the contract to Van Dieman reportedly is about $60 million (Metal Bulletin, 2005b).

The Tasmanian State Government granted a lease to Van Dieman to mine tin and sapphires north of Gladstone in northeast Tasmania. Tasmanian Government officials announced that the tin and sapphires were contained within alluvial wash from an old river channel near the historic Scotia Lead alluvial tin mine. In the 1920s, the Scotia Mine sluiced material from the banks of the Ringarooma River to extract tin. The new mine will use conventional excavation equipment, processing the material through crushing and screening plants (TIN World, 2005).

Australia Oriental Minerals NL (AOM) (North Sydney) announced that it had begun exploration work at two tin deposits. The Tingha property was considered a resource which could support a 4,000-t/yr operation with a 10-year life, and the Emmaville property could support a 3,000-t/yr mine with a 5-year life. Drilling programs would begin in 2006 to confirm these expectations. The major shareholder in AOM was Malaysia Smelting Corp. (CRU Tin Monitor, 2005a).

Bolivia.—Glencore International AG (Baar, Switzerland) purchased Cia. Mineral del Sur (Comsur) for $220 million. Comsur mines gold, lead, silver, tin, and zinc in Argentina and Bolivia. Glencore intends to make immediate investments in the company to improve mining operations. A $20 million project will be undertaken in the region to recover metal from 40 years worth of tailings. A program will be started to upgrade equipment and processes at Empresa Metalurgica Vintos (a subsidiary of Comsur) 11,000-t/yr tin smelter in Oruro in Southwest Bolivia. The smelter is coowned by Commonwealth Development Corp. plc. (London, United Kingdom) (American Metal Market, 2005a).

The state mining organization, Corporation Minera de Bolivia, announced the reactivation of two metallurgical plants. One of the two plants was the La Palca tin facility. Built during

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the 1980s with aid from the former Soviet Union, La Palca never operated satisfactorily owing to a lack of suitable ores (Platts Metals Week, 2005b).

Brazil.—Grupo Paranapanema (Sao Paulo), the country's leading producer of nonferrous metals, announced plans to expand its production of tin. It intended to double production at its Mamore division to more than 15,000 t/yr from the 7,500 t of tin reported for 2004. Completion was scheduled for late 2007 (Metal-Pages, 2005a§).

Cesbra, controlled by the Brascan Group (Toronto, Ontario, Canada), announced plans to double tin production at its Itapua do Oeste Mine in Rondonia from 3,000 t/yr to 1,500 t/yr by 2007. About 70% of the capital expenditure would be financed by the BNDES development bank (CRU Tin Monitor, 2005c).

Canada.—Dofasco Inc. (Toronto), a major Canadian steelmaker, accepted an acquisition offer from ThyssenKrupp AG (Düsseldorf, Germany). The German steelmaker agreed to pay $4.1 billion for Dofasco. Dofasco produces tinplate at its steel plant in Hamilton (American Metal Market, 2005c).

A new firm is pursuing a unique recycling niche market. Original Bottle Cap Lure Co., Quebec, formed in 2001, collects bottle caps from bars, restaurants, and trade shows, and makes fishing lures from them. Most bottle caps are made from tinplate (American Metal Market, 2005b).

China.—Reports indicated that China, the world's leading tin producer from mine and smelter sources, was experiencing a steady rise in tin imports in 2005 as the supply of domestic tin concentrate remained tight. Chinese tin smelters were reportedly importing pig tin mainly from Indonesia and Malaysia and then refining it to 99.85% tin.

Yunnan Tin Company Group Ltd. (YTL) announced that Yufeng Mining Co. would soon launch a tin mining and concentrating project at the Wuchangping Tin Mine in Chenzhou City (Hunan Province). According to a geologic report prepared by the Hunan Province Xiangnan Bureau of Geology and Mineral Exploration, Wuchangping was estimated to hold 7.6 Mt of tin ore, containing about 47,700 t of metal at a grade of 0.63% tin. In March, YTL purchased 65% of the stock of Shenzhen Juhui Mining Investment Co. Ltd. that controls most of Yufeng Mining Co., so YTL indirectly obtained a 5-year mining right over the Wuchangping Tin Mine (China Metal Market, 2006b). YTL announced that its tin output was expected to reach 60,000 t in 2006. In 2005, YTL set up joint ventures for a crude tin smelter, expected to come online in June 2006 (China Metal Market, 2006a).

Liuzhou China Tin, which is the second-ranked tin producer in China, has had difficulty securing sufficient tin concentrate feedstock in recent years and has been subject to several takeover bids. Liuzhou announced two cooperation agreements with major Indonesian companies. An agreement with the AG Group covered joint exploration in Indonesia, with the AG Group providing funding for some investment projects in Guangxi, China (CRU Week in the News, 2005g§).

Congo (Kinshasa).—A report by the nongovernmental monitoring organization Global Witness estimated that output of tin-in-concentrate in Congo (Kinshasa) rose to 8,300 t in 2004 from 2,900 t in 2003, with a significant proportion of production exported illegally via neighboring Rwanda. Rwanda's concentrate exports were thought to be more than five times local mine production, estimated to be about 300 t/yr. The report indicates that Congo (Kinshasa) tin concentrate was either flown to Kigali in Rwanda for transport to Mombassa or Dar se Salaam, or processed at the Metal Processing Association smelter just inside the Rwandan border at Gisenyi. The smelter currently produces about 200 t/yr of refined tin, all of which goes to the tinplate industry in South Africa, although the company is planning to expand its capacity to 5,000 t/yr (CRU Week in the News, 2005d§).

Egypt.—Gippsland Ltd. (Claremont, Australia) announced that it planned to carry out additional pilot-plant test work related to the financing of its Abu Dabbab tantalum-tin project in Egypt. The company hoped to achieve 10% to 20% higher head grades than those used in its November 2004 feasibility study, increasing planned capacity to 330,000 kg/yr (720,000 pounds per year) of tantalum and 1,700 t/yr of tin (CRU Week in the News, 2005f§).

Germany.—Steel producers Thyssenkrupp AG (Düsseldorf) announced plans to complete a 240,000-t/yr expansion of its Rasselstein tinplate operation by the end of 2005. In 2004, the firm stated its objective of spending $197 million on increasing capacity at its only tinplate facility at Andernach to 1.44 Mt/yr making it the world's leading single-plant producer of tinplate. With the expansion, Rasselstein will have five electrolytic tinning lines and three continuous annealing lines. Demand for tin mill products for beverage cans in Germany, Europe's leading beverage market, declined sharply during the 2 years following the introduction of a mandatory deposit system. Company officials were optimistic, however, that an increase in tinplate demand in Eastern Europe and the Commonwealth of Independent States would offset the decrease in German demand (Platts Metals Week, 2005e).

Indonesia.—The Government announced plans for a joint venture between Indonesia's PT Koba Tin [Malaysia Smelting Corp. Bhd's (MSC) 75%-owned Indonesian subsidiary], state-owned PT Timah TGK, and the local government of Bangka Belitung. Indonesia's tin smelters have a capacity of 98,000 t/yr, but some analysts estimate the country's tin mine production to be 110,000 t/yr. As a result, some of Indonesia's tin is smelted in other countries (Platts Metals Week, 2005d).

The country's major tin producer, Timah, started up its new tin smelter on Kundar Island, part of the Riau Islands, in June. The smelter was expected to produce 5,000 to 6,000 t/yr of refined tin, freeing up capacity at Timah's main smelter at Mentok on Bangka Island to treat slags which have been stockpiled in the past few years. Timah's total refined tin production capacity is now estimated to be 53,000 t/yr, although current production is 42,000 t/yr. Currently, 6 of Timah's 15 operating offshore dredges are located near Kundar, which is much closer to Singapore than Bangku (CRU Tin Monitor, 2005c).

The Indonesian small tin mines on Bangku and Belitung Islands, known locally as "tambang unconventional," were estimated to be producing about 84,000 t/yr of tin-in-concentrate, or about one quarter of world production. About one-half of this material was delivered to Timah and PT Koba, and the balance to the small independent tin smelters, which

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have started up since late 2003, and may number about 20. Any changes in these volumes are likely to have a major influence on the world supply and demand position. There are almost 6,000 small tin mines operating on the two major companies' leases (about 4,500 on Timah land and 1,400 on PT Koba property). These mines typically employ five to six workers and produce one metric ton of tin grade each month (20% tin) concentrate using simple hydraulic separation. There also has been a substantial rise in activity elsewhere in Bangku (the Timah and Koba Tin leases cover only 20% to 25% of the land area), particularly on the beaches and in shallow water offshore on the north coast of the island. Mining is also done in rivers. These small producers sell their output to collectors/traders who often upgrade the concentrates to 70% tin content (CRU Tin Monitor, 2005b).

Malaysia.—MSC (Butterworth) signed cooperation agreements with several Indonesian companies that hold exploration permits on Bangka Island, the country's tin production center. The agreements are between its 100%-owned subsidiary PT MSC Indonesia and PT Mutiara Prima Sejahtera, PT Permuta Mustika Rajawali, and PT Prima Stania Nusantara which together hold permits covering nearly 6,000 hectares. MSC has budgeted about $3 million for exploration in the area and would take a 75% share in any mining operations developed. MSC's 75%-owned Indonesian subsidiary PT Koba Tin produced 23,400 t of refined tin in 2004. This new agreement is part of the company's plan to expand its mining interests, moving away from its traditional role as a custom smelter (CRU Week in the News, 2005d§).

Peru.—Minsur S.A. (Lima) announced a small increase in capacity at its Funsur tin smelter and refinery near Pisco. Minsur is aiming to step up production to some 42,000 t in 2005. Minsur is in the process of switching to natural gas from oil to generate power for the smelter, and may import about 3,000 t of tin concentrates to supplement material from its own San Rafael Mine. Until now its refined tin production had been constrained by the capacity of its own mine, which produced 41,400 t of tin-in-concentrate in 2004 (CRU Week in the News, 2005b§).

Minsur announced plans to build a tailings retreatment plant at its large San Rafael tin mine by 2007. The proposed new facility could treat about 5,000 metric tons per day of tin tailings to 9,000 t/yr of tin (CRU Week in the News, 2005d§).

Philippines.—Global Steel Philippines (GSP) (Manila) became the country's sole tinplate producer at its Iligan steel plant on the island of Mindanao. GSP's tinplating capacity is 150,000 t/yr. GSP is owned by Global Steel Holdings Ltd., the international investment arm of Ispat Group (India) (Metal Bulletin, 2005a).

Russia.—The Russian Economic Development and Trade Ministry has been considering abolishing the import duty on tin ore and concentrates. The 5% tariff was suspended at the beginning of 2005 for a period of 9 months (Metal Pages, 2005b§).

South Africa.—Centurion Gold Holdings Inc. (Johannesburg) signed a memorandum of understanding to acquire the assets of Zaaiplaats Tin Mining Pty. Ltd. (South Africa). The Zaaiplaats Mine was formerly operated by a subsidiary of Anglo American Plc (London, United Kingdom) and ceased production owing to low tin prices in 1992. The Ziaaiplaats mines are located in the Limpopo Province of South Africa, in the northern Bushreld complex. The tin mines have produced in excess of 17,000 t of tin in their history. Centurio is considering producing up to 2,500 t/yr by a combination of mining and tailings retreatment. The firm anticipated developing the project jointly with Mine Waste Management (Ottawa, Ontario, Canada) which specializes in tailings treatment and mine rehabilitation (CRU Week in the News, 2005a§).

Spain.—Goldtech Mining Corp. (Alberta, Canada) was proceeding toward reopening the Golpejas tin property, located west of Salamanca, Spain. Drilling to help evaluate the property is in progress, and if it shows good results, Goldtech plans to install a pilot plant and eventually a full-sized plant, or rehabilitate the old mill already on the property, to recover tin and tantalite (Platts Metals Week, 2005c).

Thailand.—Mine production of tin in Thailand leveled off in 2005 after a long decline. Production was about 600 t, compared with 586 t in 2004, 793 t in 2003, and 1,130 t in 2002. Tongkah Harbour Plc (Bangkok) was the main producer, using contractors to operate dredges in offshore operations. The number of dredges dropped from three in 2002 to one in 2003. Production ceased altogether in April 2005, and this was attributed to the Government's 20% royalty on tin sales. The royalty was being renegotiated, and if it is revised downwards, Tongkah expected to proceed with exploration of a new offshore area that was expected to contain almost 50,000 t of tin (Mining Journal, 2005).

The Thailand Smelting and Refining Co. Ltd. tin smelter in Phuket, which became part of Billiton Ltd. in 1972, more recently became part of the Amalgamated Metal Corp. Group. The smelter has a production capacity of 36,000 t/yr of refined tin, but output has been low in recent years primarily as a result of a shortage of concentrates from Indonesia and Peru, as production in those countries has become more fully integrated. In 2004, however, production increased to 20,800 t from 15,400 t in 2003 (Mining Journal, 2005).

Current Research and Technology

Aguila Technologies Inc. (San Marcos, CA) announced the development of a lead-free solder that may provide manufacturers with a more cost-effective and easier-to-use option. The major hurdle in moving to lead-free solders has been that alternatives melt at higher temperatures, forcing other nearby materials to have to withstand higher temperatures. Traditional lead-base solder is an alloy of tin and lead, melting at nearly 183° C to 190° C. The most common lead-free solders are alloys of tin and silver (and sometimes copper) which melt between 217° C and 229° C. The new solder reportedly does not require any flux or cleaning and leaves no residue (Advanced Materials & Processes, 2006).

Outlook

Domestic demand for primary tin is expected to increase moderately in the next few years, at a rate of about 2% per year. That rate, however, will probably double in a few years if new

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applications—especially those in which tin is substituted for toxic materials, such as lead-free solders—find acceptance in the marketplace.

World tin reserves appear to be adequate to meet foreseeable demand. Secondary sources of tin are likely to remain an important component of supply, especially in the United States. NDS tin stocks are expected to be exhausted within about 2 more years at the current rate of sales. Domestic tin requirements will probably continue to be met primarily through imports.

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TABLE 1
SALIENT TIN STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Production, secondary, contained tin[e]	metric tons	6,700	6,760	5,500	5,240 r	11,800
Exports, refined tin	do.	4,350	2,940	3,690	3,650	4,330
Imports for consumption, refined tin	do.	37,500	42,200	37,100	47,600	37,500
Consumption, contained tin:						
Primary	do.	34,200	34,000	32,900	36,700 r	32,200
Secondary	do.	7,630	5,830	4,510	7,990 r	9,170
Stocks, yearend, U.S. industry, contained tin	do.	9,620	8,930 r	7,960	8,980 r	8,270
Prices, average, contained tin:						
New York, NY market	cents per pound	211.48	194.75	232.36	409.37	360.93
Platts Metals Week composite	do.	314.88	291.97	339.78	547.30	483.04
London, United Kingdom	do.	203.00	184.00	222.00	385.00	334.00
Kuala Lumpur, Malaysia	do.	200.77	184.35	221.67	385.11	333.55
World, production, contained tin:						
Mine	metric tons	246,000 r	233,000 r	258,000 r	298,000 r	292,000 e
Smelter:						
Primary	do.	272,000 r	266,000 r	268,000 r	297,000 r	329,000 e
Secondary	do.	16,200	14,200	11,900	11,700 r	20,200 e
Undifferentiated	do.	--	70 r,e	200 r	200 r,e	200 e

[e]Estimated. [r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits, except prices.

TABLE 2
U.S. CONSUMPTION OF PRIMARY AND SECONDARY TIN[1]

(Metric tons of contained tin)

	2004	2005
Stocks, January 1[2]	7,680 r	8,070
Net receipts during year:		
Primary	40,800 r	33,400
Secondary	4,160 r	5,790
Scrap	4,350	3,840
Total receipts	49,300 r	43,000
Total available	57,000 r	51,100
Tin consumed in manufactured products:		
Primary	36,700 r	32,200
Secondary	7,990 r	9,170
Total	44,700 r	41,400
Intercompany transactions in scrap	496	407
Total processed	45,200 r	41,800
Stocks, December 31 (total available less total processed)	11,800 r	9,280

[r]Revised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes tin in transit in the United States.

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TABLE 3
U.S. CONSUMPTION OF TIN, BY FINISHED PRODUCT[1]

(Metric tons of contained tin)

Product	2004			2005		
	Primary	Secondary	Total	Primary	Secondary	Total
Alloys, miscellaneous[2]	W	W	W	W	W	W
Babbitt	728 r	W	728 r	554	W	554
Bar tin	680	W	680	707	W	707
Bronze and brass	1,230	1,840	3,070	1,240	1,960	3,200
Chemicals	9,120	W	9,120	8,360	W	8,360
Collapsible tubes and foil	W	W	W	W	W	W
Solder	13,100 r	5,890 r	19,000 r	9,630	7,040	16,700
Tinning	798	--	798	790	--	790
Tinplate[3]	7,700	--	7,700	7,250	--	7,250
Tin powder	W	W	W	W	W	W
Type metal	W	W	W	W	W	W
White metal[4]	937	W	937	W	W	W
Other	2,370	254	2,630	3,680	172	3,860
Total	36,700 r	7,990 r	44,700 r	32,200	9,170	41,400

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes terne metal.
[3]Includes secondary pig tin and tin acquired in chemicals.
[4]Includes pewter, britannia metal, and jewelers' metal.

TABLE 4
U.S. INDUSTRY YEAREND TIN STOCKS[1]

(Metric tons)

	2004	2005
Plant raw materials:		
Pig tin:		
Virgin[2]	6,660 r	6,390
Secondary	595 r	660
In process[3]	892	863
Total	8,150 r	7,910
Additional pig tin:		
Jobbers-importers	762	278
Afloat to United States	62	80
Total	824	358
Grand total	8,980 r	8,270

rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes tin in transit in the United States.
[3]Data represent scrap only, tin content.

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TABLE 5
U.S. STOCKS, RECEIPTS, AND CONSUMPTION OF NEW AND OLD SCRAP AND TIN RECOVERED, BY TYPE OF SCRAP[1]

(Metric tons)

Type of scrap	Gross weight of scrap: Stocks, January 1	Receipts	Consumption: New	Consumption: Old	Consumption: Total	Stocks, December 31	Tin recovered[e]: New	Tin recovered[e]: Old	Tin recovered[e]: Total
2004:									
Copper-base scrap:									
Ingot makers	4,030 r	73,800 r	17,900	55,800 r	73,700 r	4,140 r	712	2,290 r	3,000 r
Brass mills[2]	--	22,800	22,800	--	22,800	--	469	--	469
Foundries and other plants	1,940	27,600	17,300	10,800	28,100	1,420	W	397	397
Total	XX	XX	XX	XX	XX	XX	1,180	2,680	3,870 r
Lead-base scrap	27,500 r	1,250,000 r	W	1,230,000 r	1,230,000 r	30,300 r	W	2,560 r	2,560 r
Tin-base scrap[3]	W	W	W	W	W	W	2,410	W	2,410
Grand total	XX	XX	XX	XX	XX	XX	3,590	5,240 r	8,830 r
2005:									
Copper-base scrap:									
Ingot makers	4,140	68,300	17,100	51,400	68,500	3,960	W	2,130	2,130
Brass mills[2]	--	W	W	--	W	--	1,740	--	1,740
Foundries and other plants	1,420	26,700	W	W	W	1,490	W	460	460
Total	XX	XX	XX	XX	XX	XX	1,740	2,590	4,330
Lead-base scrap	30,300	1,360,000	W	1,340,000	1,340,000	28,700	541	9,170	9,710
Tin-base scrap[3]	W	W	W	W	W	W	W	W	W
Grand total	XX	XX	XX	XX	XX	XX	2,280	11,800	14,000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data. XX Not applicable. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Consumption is assumed to be equal to receipts.
[3]Includes tinplate and other scrap recovered at detinning plants.

TABLE 6
U.S. EXPORTS OF TIN IN VARIOUS FORMS[1]

Year	Tinplate and terneplate: Quantity (metric tons, gross weight)	Tinplate and terneplate: Value (thousands)	Ingots and pigs: Quantity (metric tons)	Ingots and pigs: Value (thousands)	Tin scrap and other tin-bearing material except tinplate scrap[2]: Quantity (metric tons, gross weight)	Tin scrap and other tin-bearing material except tinplate scrap[2]: Value (thousands)
2004	262,000	$169,000	3,650	$25,700	16,800	$42,900
2005	252,000	188,000	4,330	30,500	32,800	51,200

[1]Data are rounded to no more than three significant digits.
[2]Includes rods, profiles, flakes, tubes, and pipes.

Source: U.S. Census Bureau.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION OF TIN IN VARIOUS FORMS[1]

Year	Miscellaneous,[3] value (thousands)	Dross, skimmings, scrap residues, tin alloys, n.s.p.f.[2]: Quantity (metric tons, gross weight)	Dross, skimmings, scrap residues, tin alloys, n.s.p.f.[2]: Value (thousands)	Tinplate and terneplate: Quantity (metric tons, gross weight)	Tinplate and terneplate: Value (thousands)	Tin compounds: Quantity (metric tons, gross weight)	Tin compounds: Value (thousands)	Tinplate scrap: Quantity (metric tons, gross weight)	Tinplate scrap: Value (thousands)
2004	7,080	5,790	$24,500	328,000	$215,000	635	$6,030	9,650	$2,020
2005	8,010	9,930	28,500	391,000	300,000	564	5,720	16,800	3,160

[1]Data are rounded to no more than three significant digits.
[2]Not specifically provided for.
[3]Includes tinfoil, tin powder, flitters, metallics, manufactures, and n.s.p.f.

Source: U.S. Census Bureau.

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TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF UNWROUGHT TIN METAL, BY COUNTRY[1]

Country	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Australia	121	$963	--	--
Belgium	70	740	34	356
Bolivia	5,060	38,200	5,400	43,400
Brazil	4,330	33,600	2,150	16,100
Canada	58	480	13	89
Chile	281	1,950	20	171
China	5,310	44,800	4,510	34,700
Indonesia	4,660	37,300	5,220	37,200
Japan	540	4,320	--	--
Malaysia	6,600	56,900	1,530	12,200
Peru	19,600	163,000	18,300	138,000
Taiwan	21	419	--	--
Thailand	500	4,510	45	358
United Kingdom	97	481	67	502
Other	380	2,680	216	1,560
Total	47,600	390,000	37,500	285,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 9
TIN: WORLD MINE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005[e]
Australia	9,602	6,268	3,819	800	2,800 [3]
Bolivia	12,352	15,242	16,755	17,569 [r]	18,694 [3]
Brazil	13,016	12,063	12,217	12,468 [r]	12,500 [p]
Burma[4]	659 [r]	456 [r]	606 [r]	526 [r]	500
Burundi	3 [r]	--	5 [r]	10 [e]	10
China[e]	95,000	62,000	102,000	118,000 [r]	120,000
Congo (Kinshasa)[e]	50	20	40	80	80
Indonesia	61,862	88,142	71,694	65,772 [r]	80,000 [3]
Kyrgyzstan[e]	300	300	--	--	--
Laos	490	366	360 [e]	400 [r]	450
Malaysia	4,972	4,215	3,359	2,745 [r]	3,000 [3]
Mexico	8	9	21 [e]	24	17
Nambia	-- [e]	-- [e]	43	15	--
Niger	9 [e]	11	11 [e]	3,100 [r]	3,100
Nigeria[e, 5]	2,870 [3]	790 [3]	1,800 [r]	1,000 [r]	1,500
Peru	38,182	38,815	40,202	67,675 [r]	42,145 [3]
Portugal	1,174	361	200 [e]	500	200
Russia[e]	2,000	1,300	2,000	2,500	3,000
Rwanda	169	197	192 [e]	300 [r]	300
Spain[e]	2	2	2	2	2
Thailand	1,950	1,130	793 [r]	586 [r]	600 [3]
Uganda	18	--	1	2	2
Vietnam[e]	1,700 [r]	1,700 [r]	2,100 [r]	3,500 [r]	3,500
Total	246,000 [r]	233,000 [r]	258,000 [r]	298,000 [r]	292,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 18, 2006.

[3]Reported figure.

[4]Includes content of tin-tungsten concentrate.

[5]Concentrate gross weight reported, estimated 62% tin content.

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TABLE 10
TIN: WORLD SMELTER PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005[e]
Australia:					
Primary	1,171	791	597	478 [3]	600 [4]
Secondary[e]	300	300	300	300	300
Total[e]	1,471	1,091	897	778	900
Belgium, secondary[e]	8,000	6,000	5,000	5,000	7,000
Bolivia, primary	11,292	10,976	11,000 [r]	13,627 [r]	14,000
Brazil:					
Primary	12,168	11,675	10,761	11,512 [r]	11,500 [p]
Secondary[e]	250	250	250	250	250
Total[e]	12,400	11,900	11,000	11,800 [r]	11,800
Bulgaria, secondary[e]	10	10	10	10	10
Burma, primary[e]	30	30	30	30	30
China, primary[e]	105,000	82,000	98,000	115,000	124,000
Czech Republic, secondary[e]	100	100	100	100	100
Denmark, secondary[e]	100	100	100	100	100
Greece, secondary[e]	150	150	100	100	100
Indonesia, primary	53,470	67,455	66,284 [r]	49,872 [r]	65,000
Japan, primary	668	659	662	707	754 [4]
Malaysia, primary	30,417	30,887	18,250	33,914 [r]	36,870 [4]
Mexico, primary	1,789	1,748	1,769	1,775	1,700 [4]
Nigeria, primary[e]	25	26	25	25	25
Norway, secondary[e]	50	50	50	50	50
Peru, primary	27,683	35,828	39,181	41,613 [r]	36,733 [4]
Russia:[e]					
Primary	4,569 [4]	4,615 [4]	4,100 [r]	4,570 [r]	5,000
Secondary	500	500	500	500	500
Total	5,070	5,120	4,600 [r]	5,070 [r]	5,500
Rwanda	--	70 [r, e]	200 [r]	200 [r, e]	200 [4]
Spain, secondary[e]	25	25	25	25	10
Thailand, primary	22,387	17,548	15,400 [r]	20,800 [r]	29,400
United States, secondary	6,700	6,760	5,500	5,240 [r]	11,800 [4]
Vietnam, primary[e]	1,700 [r]	1,700 [r]	2,100 [r]	3,500 [r]	3,500
Grand total	289,000 [r]	280,000	280,000	309,000 [r]	350,000
Of which:					
Primary	272,000	266,000 [r]	268,000	297,000 [r]	329,000
Secondary	16,200	14,200	11,900	11,700 [r]	20,200
Undifferentiated	--	70 [r, e]	200 [r]	200 [r, e]	200 [4]

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Whenever possible, total output has been separated into primary (from ores and concentrates) and secondary (tin metal recovered from old scrap). This table reflects metal production at the first measurable stage of metal output. Table includes data available through July 18, 2006.

[3]Exports.

[4]Reported figure.

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TITANIUM

By Joseph Gambogi

Domestic survey data and tables were prepared by Robin C. Kaiser, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Gross world consumption of titanium mineral concentrates increased by 3% compared with that of 2004, and production increased by 8% (Mineral Sands Report, 2006a). The industry continued the development of new heavy-mineral mine capacity, with most development projects centered in Australia. U.S. consumption of titanium mineral concentrates fell by about 11% compared with that in 2004. The closure of one titanium dioxide (TiO_2) plant in Mississippi in September, resulting from damage sustained by Hurricane Katrina, contributed to the decline in consumption. Imports continued to supply a significant portion of U.S. reported titanium concentrate consumption. Australia was the leading import source of ilmenite and rutile, and South Africa was the leading import source for titanium slag.

Global consumption of TiO_2 pigment was estimated to be 4.8 Mt, a 3.7% increase compared with consumption in 2004 (Mineral Sands Report, 2006b). According to U.S. Geological Survey (USGS) survey data, domestic consumption of TiO_2 pigment fell by 3% compared with that of 2004.

Domestic shipments of titanium mill products increased by 25%, while consumption of titanium in steel and other alloys increased by 7% compared with those of 2004. Increased demand for titanium used in titanium metal and steel production exceeded the available supply of scrap and production capacity for new metal. Prices for titanium metal products continued to rise in 2005 because of increased demand for commercial aircraft and military hardware. Because of strong demand for titanium in aerospace applications, U.S. titanium sponge producers announced plans to increase production capacity. Sales of titanium sponge from the National Defense Stockpile (NDS) exhausted U.S. Government stocks of the material by yearend.

Legislation and Government Programs

The Defense National Stockpile Center (DNSC) continued the sale of titanium sponge held in the NDS. In January, the DNSC awarded about 1,130 metric tons (t) (2.5 million pounds) of titanium sponge to the following companies for $19 million: AlloyWorks LLC, Global Titanium Inc., Keywell LLC, Specialty Metal Products Co. Inc., and Wogen Titanium Ltd. (Defense National Stockpile Center, 2005a). In March, 680 t (1.5 million pounds) of titanium sponge was awarded to Cronimet Group, Galt Alloys Inc., and Reading Alloys Inc. for $1.5 million (Defense National Stockpile Center, 2005b). In November, the DNSC awarded 680 t of sponge to RMI Titanium Co., Specialty Metal Products, and Titanium Metals Corp. (Timet) for $16 million. The November sale exhausted the DNSC's inventory of sponge (Defense National Stockpile Center, 2005c).

The Defense Advanced Research Projects Agency (DARPA) continued to fund work on its Titanium Initiative whose objective is to develop revolutionary processes for the low-cost extraction of titanium metal from oxide ores. DARPA's Titanium Initiative included electrolytic processes similar to those that reduced the cost of aluminum from that of a precious metal to an everyday material (Defense Advanced Research Projects Agency, 2006§[1]).

Production

Mineral Concentrates.—Titanium mineral concentrates of economic importance include ilmenite, leucoxene, rutile, synthetic rutile, and titaniferous slag. Mining of titanium minerals is usually performed using surface methods. Dredging and dry mining techniques are used for the recovery of heavy minerals. Gravity spirals are used to separate the heavy-minerals suite, while magnetic and high-tension separation circuits are used to separate the heavy-mineral constituents. Ilmenite is often processed to produce a synthetic rutile or titaniferous slag. Although numerous technologies are used to produce synthetic rutile, nearly all are based on either selective leaching or thermal reduction of iron and other impurities in ilmenite. Titaniferous slag with a TiO_2 content of 75% to 95% is produced commercially using pyrometallurgical processes.

U.S. mineral concentrate producers were DuPont Titanium Technologies [a subsidiary of E.I. du Pont de Nemours & Co. (DuPont)] and Iluka Resources, Inc. [a subsidiary of Iluka Resources Ltd.]. DuPont's mining operations near Starke, FL, produced a mixed product containing ilmenite, leucoxene, and rutile that was used as a captive feedstock in DuPont's TiO_2 pigment plants. Iluka produced titanium mineral concentrates from its heavy-mineral sand operations at Green Cove Springs, FL, Lulaton, GA, and Stony Creek, VA. Heavy-mineral concentrate from the Lulaton mine was trucked to the dry separation plant at Green Cove Springs. Iluka's Stony Creek operation produced ilmenite concentrate using dry mining techniques.

In December, Iluka announced plans for a staged closure of its Florida and Georgia mining operations beginning in 2006. The closure was attributed in part to financial losses from mining small, thin, and disparate low-grade deposits and rising operating costs. Although the Florida operations had been producing heavy minerals since 1972, the Georgia operations were commissioned in 2004 (Iluka Resources Ltd., 2005§).

Metal.—Commercial production of titanium metal involves the chlorination of titanium-containing mineral concentrates to produce titanium tetrachloride ($TiCl_4$), which is reduced with magnesium (Kroll process) or sodium (Hunter process) to form a commercially pure form of titanium metal. As the metal is formed, it has a porous appearance and is referred to as sponge. Titanium ingot is produced by melting titanium sponge or scrap or a combination of both, usually with various other alloying

[1]References that include a section mark (§) are found in the Internet References Cited section.

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elements, such as aluminum and vanadium. Electron beam, plasma, scull, and vacuum-arc melting are the commercial methods used to produce ingot. Titanium mill products are produced from the drawing, forging, and rolling of titanium ingot or slab into products of various sizes and shapes. These mill products include billet, pipe and tube, plate, rod and bar, sheet, strip, and wire. Titanium castings are produced by investment casting and rammed graphite mold casting. Ferrotitanium is usually produced by induction melting of titanium scrap with iron or steel. The two standard grades of ferrotitanium that are normally produced contain 40% and 70% titanium.

U.S. producers of titanium sponge in 2005 were The Alta Group and Timet. Alta's 340-metric-ton-per-year (t/yr) plant in Salt Lake City, UT, produced titanium sponge by the Hunter process and supported the company's production of electronic-grade titanium. Timet's 8,600-t/yr Henderson, NV, plant produced titanium sponge by the traditional Kroll process combined with vacuum distillation (table 2). Data on domestic production of titanium sponge are withheld to avoid disclosing company proprietary data. Of the 85,300 t/yr of domestic ingot capacity, 20% was based on cold hearth technology; the remainder was based on vacuum-arc remelting technology.

In 2005, U.S. production of ingot rose to 48,100 t, a 16% increase compared with that of 2004. Similarly, production of mill products increased by 15% compared with that of 2004 (table 3). U.S. producers of ferrotitanium were Galt Alloys and Global Titanium. Data on production of ferrotitanium were not available.

In July, Allegheny Technologies Inc. (ATI) announced a major expansion of its titanium production capabilities. This expansion would include upgrading and restarting about one-half of ATI's idled titanium sponge facility in Albany, OR. ATI expected a production rate of 3,400 t/yr of titanium sponge from this facility beginning in the first half of 2006. In addition, ATI planned to construct a third plasma arc melt cold-hearth furnace, which was expected to come onstream by late 2006; expand high-value plate products capacity by 25%; and upgrade cold-rolling assets used in producing titanium sheet and strip products. Also included in this titanium capability expansion was a 25% increase across ATI's titanium production system, including increases in vacuum arc remelt capacity, electron beam cold hearth melting capacity, and forging reheat capacity (Allegheny Technologies Inc., 2005§).

In May, Timet announced that it planned to expand its titanium sponge facility in Henderson. The company expected to complete this expansion by the first quarter of 2007, which will provide the capacity to produce an additional 4,000 t/yr of sponge (Titanium Metals Corp., 2006§). The plant had been idled since 2001.

In September, Honeywell Electronic Materials (a subsidiary of Honeywell International Inc. and parent firm of Alta) announced that it planned to increase production of titanium sponge, although no quantity was specified. Honeywell Electronic Materials produced sodium-reduced titanium sponge at its Salt Lake City, UT, facility for its electronics business. At its Fombell, PA, facility, Honeywell refined titanium sponge for semiconductors into high-purity material that is 99.999% pure with very low metallic impurity and gas levels using a hydride-dehydride process. Honeywell began selling sponge externally to meet growing demand and planned to increase the quantity available (Honeywell Electronic Materials, 2005§).

TiO_2 Pigment.—TiO_2 pigment is produced from titanium mineral concentrates by either the chloride route or the sulfate route. In the chloride process, rutile is converted to $TiCl_4$ by chlorination in the presence of petroleum coke. $TiCl_4$ is oxidized with air or oxygen at about 1,000° C, and the resulting TiO_2 is calcined to remove residual chlorine and any hydrochloric acid that may have formed in the reaction. Aluminum chloride is added to the $TiCl_4$ to assure that virtually all the titanium is oxidized into the rutile crystal structure. In the sulfate process, ilmenite or titanium slag is reacted with sulfuric acid. Titanium hydroxide is then precipitated by hydrolysis, filtered, and calcined. Although either process may be used to produce pigment, the decision to use one process instead of the other is based on numerous factors, including raw material availability, freight, and waste disposal costs. In finishing operations, the crude form of the pigment is milled to produce a controlled distribution of particle size and surface treated or coated to improve its functional behavior in different media. Some typical surface treatments include alumina, organic compounds, and silica.

TiO_2 pigment produced by either process is categorized by crystal form as either anatase or rutile. Rutile pigment is less reactive with the binders in paint when exposed to sunlight than is the anatase pigment and is preferred for use in outdoor paints. Anatase pigment has a bluer tone than rutile, is somewhat softer, and is used mainly in indoor paints and in paper manufacturing. Depending on the manner in which it is produced and subsequently finished, TiO_2 pigment can exhibit a range of functional properties, including dispersion, durability, opacity, and tinting.

U.S. production of TiO_2 pigment in 2005 was 1.31 Mt, 14% less than that in 2004 (table 5). U.S. producers of TiO_2 pigment were DuPont, Kerr-McGee Corp., Louisiana Pigment Co. LP (an NL Industries Inc. and Huntsman Corp. joint venture), and Millennium Inorganic Chemicals Inc. (table 4). TOR Minerals International, Inc. produced a TiO_2 pigment from finely ground synthetic rutile.

Although DuPont's DeLisle, MS, TiO_2 plant escaped major structural damage from Hurricane Katrina's high winds, floodwater significantly damaged process control systems, other electrical and electronic equipment, and plant infrastructure. DuPont expected that repairs would take about 3 months, and the company planned to have the plant running at full capacity by spring 2006 (DuPont Titanium Technologies, 2005). Other TiO_2 plants in the Gulf Coast area were closed in advance of Hurricanes Katrina and Rita, but sustained only minor damage that did not require significant downtime.

Consumption

Mineral Concentrates.—On a gross weight basis, 96% of the domestic consumption of titanium mineral concentrates was used to produce TiO_2 pigment. The remaining 4% was used to produce miscellaneous other products including titanium metal, welding rod coatings, and fluxes. Based on TiO_2 content, domestic consumption of titanium mineral concentrates was 1.39 Mt, a 7% decrease compared with that of 2004 (table 6). Consumption data for titanium concentrates were developed by

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the USGS from a voluntary survey of domestic operations. Of the 16 operations canvassed, 10 responded, representing 64% of the consumption data in table 6. Data for nonrespondents were estimated based on prior-year consumption with some adjustments for current-year trends.

Metal.—Titanium metal alloys are used for their high strength-to-weight ratio and corrosion resistance. Driven by demand from the aerospace industry, consumption of titanium sponge and scrap by the domestic titanium industry increased by 31% compared with that of 2004 (table 3). Scrap supplied a calculated 50% of ingot feedstock. Estimated U.S. mill product usage by application was as follows: aerospace, 75%, and nonaerospace uses, 25%. Nonaerospace uses included those in the consumer goods, marine, medical, oil and gas, pulp and paper, and specialty chemical industries.

A significant quantity of titanium in the form of ferrotitanium, scrap, and sponge is consumed in the steel and nonferrous alloy industries. Consumption by the steel industry is largely associated with the production of stainless steels and is used for deoxidation, grain-size control, carbon and nitrogen control, and stabilization typically in interstitial-free, stainless, and high-strength low-alloy steels. Reported domestic consumption of titanium products in steel and other alloys was 11,000 t, a 7% increase compared with that of 2004 (table 7).

TiO_2 Pigment.—In the United States, apparent consumption of TiO_2 pigment was 1.13 Mt, a 3% decrease compared with that of 2004 (table 5). The leading uses of TiO_2 pigment, based on TiO_2 pigment shipments in the United States, were paint and coatings (63%), plastics and rubber (24%), and paper (12%) (table 8). Other uses (1%) included catalysts, ceramics, coated fabrics and textiles, floor coverings, printing ink, and roofing granules.

In the paint and coatings industry, TiO_2 pigment is used in architectural, equipment, and special-purpose applications and is widely used in white and color formulations. The TiO_2 content for paint and coatings varies significantly.

In plastics, TiO_2 pigment provides opacity and acts as a barrier against ultraviolet light degradation. TiO_2 pigment often is introduced as pellets containing up to 50% by weight TiO_2 in a carrier resin; however, liquid and dry concentrates also are used by the industry. The TiO_2 content of plastics normally ranges from 3% to 25% by weight of the finished product. Examples of plastic applications that use TiO_2 pigment include polyethylene bags and vinyl window frames.

TiO_2 pigment in paper products provides opacity and brightness. The paper industry consumes TiO_2 pigment as filler and in coatings. Paper products contain a high percentage of non-TiO_2-base minerals as filler material with the typical TiO_2 content less than 5% of the dry weight of paper. Anatase-grade pigment is preferred in the paper industry because it is less abrasive to papermaking machinery.

Stocks

Insufficient data were available to determine yearend consumer inventories of titanium mineral concentrates and TiO_2 pigment producer stocks. Owing to sales from the DNSC inventory, Government stocks of sponge fell to zero, a 2,510 t decrease compared with those of 2004. Industry stocks of sponge decreased by 43%. Stocks of scrap decreased slightly to 6,900 t, and stocks of ingot increased by 8% compared with those of 2004 (table 3).

Prices

The yearend published price range for bulk rutile mineral concentrates was $460 to $480 per metric ton, compared with $430 to $480 per metric ton in 2004. The yearend price range for bagged rutile concentrates was unchanged at $550 to $650 per ton. Yearend prices of ilmenite concentrates ranged from $75 to $85 per ton (table 10). Published prices for titanium slag were not available. Based on U.S. Customs Service data, yearend unit value of slag imports ranged from $390 to $555 per ton in 2005 compared with $347 to $466 per ton in 2004.

Because of the constrained supply of TiO_2 pigment caused by Hurricane Katrina, yearend published prices for anatase- and rutile-grade pigment increased compared with those of 2004. The Bureau of Labor Statistics producer price index for TiO_2 pigment significantly increased to 164.5 in December 2005 from 146.7 in December 2004 (U.S. Department of Labor, Bureau of Labor Statistics, 2006§).

Because of a significant increase in demand for commercial aircraft and military hardware, prices of titanium metal products rose considerably. The yearend unit value of titanium sponge ranged from $3.46 to $12.22 per pound in 2005, a dramatic increase compared with that of 2004. The yearend price range for titanium scrap also reflected market conditions, increasing to between $4.85 and $5.15 per pound in 2005 from between $3.80 and $4.00 per pound in 2004. The published price increase was substantiated by a 115% increase in the unit value of waste and scrap imports. Increased demand for ferrotitanium by steel producers was reflected in a significant increase in ferrotitanium prices. The published price range for ferrotitanium with 70% contained titanium was $8.50 to $9.50 per pound in 2004 compared with $6.35 to $6.45 per pound in 2004.

Foreign Trade

Mineral Concentrates.—The United States is heavily reliant on imports of titanium mineral concentrates because domestic demand for titanium minerals greatly exceeds domestic production. In 2005, exports of titanium mineral concentrate were 20,900 t, a 140% increase compared with 2004 (table 11). Exports of titanium concentrates are minor relative to imports.

Imports of titanium mineral concentrates include ilmenite, rutile, synthetic rutile, and titaniferous slag. In 2005, the combined value for all forms of titanium concentrate imports increased 9% compared with that of 2004 to $432 million. This increase was owing to increased reliance on titaniferous slag.

In 2005, imports of ilmenite were 154,000 t, a 37% decrease compared with those of 2004. The import sources of ilmenite were Australia (88%) and Ukraine (12%). The closure of sulfate-route TiO_2 pigment capacity in 2004 contributed to the overall decrease in imported ilmenite.

Imports of titaniferous slag were 667,000 t, a 46% increase compared with those of 2004. South Africa (71%) and Canada (25%) were the leading import sources of titanium slag. Of

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the total titaniferous slag imports, 4% may be misclassified by country because the country of origin did not produce titaniferous slag.

Imports of natural and synthetic rutile totaled 366,000 t. Australia (53%) and South Africa (38%) were the major import sources of natural and synthetic rutile in 2005. Although imports of natural rutile decreased compared with those of 2004, imports of synthetic rutile increased such that the rutile total increased slightly compared with those of 2004.

Imports of titaniferous iron ore from Canada, classified as ilmenite by the U.S. Census Bureau, decreased by 11% compared with those in 2004. Titaniferous iron ore was used by the steel industry to protect the crucibles of blast furnaces. In this report, imports of titaniferous iron ore from Canada are separated from ilmenite statistics (table 12).

Metal.—Prompted by a tariff classification ruling by U.S. Customs Service, the 2004 Harmonized Tariff Schedule of the United States (HTS) codes used to classify imports of titanium metal were changed. In 2004, the HTS unwrought codes for "Billet" and "Bloom, sheet bars, and slab" were eliminated. In addition, the HTS code for "Other, unwrought" was changed to 8108.20.0091 from 8108.20.0090.

Imports of titanium metal are primarily in the form of unwrought titanium. Kazakhstan (53%), Japan (39%), and Russia (6%) were the leading sources of imported titanium sponge, while Japan (24%), France (17%), the United Kingdom (17%), and Germany (13%) were the leading sources of imported waste and scrap. The leading import sources of titanium ingot were Russia (78%) and Germany (14%). Imports of titanium powder were 126 t, an 11% decrease compared with those of 2004. China (68%) was the major source of titanium powder. Imports of other unwrought forms of titanium increased by 39% compared with those of 2004.

Imports of titanium wrought products and castings are primarily in the form of bar, rod, profiles, and wire (50%) and plate, sheet, strip, and foil (19%). Russia (63%) and Japan (11%) were the major import sources of wrought products and castings. Imports of wrought products and castings increased 4% compared with those of 2004, and exports of wrought products and castings increased by 60%.

Imports of ferrotitanium and ferrosilicon titanium, primarily used in the iron and steel industry, were 16,900 t, a 143% increase compared with those of 2004. Exports of ferrotitanium and ferrosilicon titanium were 3,630 t, a 30% increase compared with those of 2004.

TiO_2 Pigment.—Although Hurricane Katrina hampered production and trade along the Gulf Coast, the United States continued to be a net exporter of TiO_2 pigment. In 2005, exports exceeded imports by a ratio of 1.5 to 1. Exports of TiO_2 pigment were 524,000 t, a 17% decrease compared with that of 2004. About 93% of exports was in the form of finished pigment with more than 80% TiO_2 content.

During 2005, 341,000 t of TiO_2 pigment was imported, a 29% increase compared with 2004 (table 14). The leading import sources of TiO_2 pigment were Canada (31%), China (14%), the United Kingdom (8%), and Germany (7%). Compared with those of 2004, imports of TiO_2 pigment containing more than 80% TiO_2 increased by 25% to 249,000 t, other TiO_2 pigment increased by 23% to 6,600 t, and unfinished TiO_2 (unmixed and not surface treated) increased by 45% to 85,800 t.

World Review

Australia.—Astron Ltd. made plans to proceed with the development of its Donald heavy-mineral sands project in Victoria. Production was scheduled to begin in 2007. Initial mine capacity was expected to be up to 500,000 t/yr of heavy minerals, including 106,000 t/yr of ilmenite and 73,000 t/yr of leucoxene and rutile (Astron Ltd., 2006§).

Australian Zircon NL completed a drilling program at its Mindarie mineral sands project in the western Murray Basin. The deposit was estimated to have 1.6 Mt of measured heavy-mineral resources. Australian Zircon expected to commence production near yearend 2006 (Australian Zircon NL, 2005§).

In December, Bemax Resources NL began mining at the Pooncarie mineral sands project in the Murray Basin. The company planned to begin trucking heavy-mineral concentrate from the Ginkgo mine to the Broken Hill mineral separation plant in 2006. The Ginkgo mine was reported to contain 5.8 Mt of heavy minerals, with a mine life of more than 25 years. During 2005, Bemax upgraded its Bunbury mineral separation plant to allow it to simultaneously process feedstock from its Western Australia (Cable Sands) and Murray Basin operations as well as toll feedstock (Bemax Resources NL, 2006§).

Iluka continued work on the development of heavy-mineral deposits in the Murray and Eucla Basins. In 2004, Iluka had started stockpiling ore for its Douglas project in the Murray Basin, Victoria. By yearend 2005, Iluka had completed mine construction and was preparing to commission the wet concentration plant for the Douglas project. A mineral separation plant located near Hamilton was expected to be completed in mid-2006. In the first year of operation, production was expected to be 180,000 t of rutile and zircon. In the northern Murray Basin, Iluka was in the prefeasibility phase in the development of its Euston and Ouyen deposits. In the Eucla Basin, Iluka continued the delineation of its Ambrosia, Jacinth, and Tripitaka deposits (Iluka Resources Ltd., 2006§).

Olympia Resources Ltd. announced the completion of a bankable feasibility study for its Keysbrook mineral sands project, south of Perth. Keysbrook was expected to have a mine life of 11 years (Olympia Resources Ltd., 2005§). Olympia has identified a reserve of 1.2 Mt of heavy minerals at Keysbrook with startup scheduled for 2007 (Olympia Resources Ltd., 2006§).

Canada.—In the first half of 2005, QIT Fer et Titane Inc. (a subsidiary of Rio Tinto plc) completed an expansion of the upgraded titanium slag (UGS) plant at Sorel, Quebec, to 325,000 t/yr. Because of strong demand, QIT announced a further $190 million expansion of the plant's capacity to 375,000 t/yr, which was expected to be completed in 2006 (Rio Tinto plc, 2006§). The UGS plant converts QIT's sulfate-grade slag containing about 80% TiO_2 into a chloride-grade slag containing about 95% TiO_2.

Titanium Corp., Inc. continued efforts to commercialize the recovery of heavy minerals from the oil sands tailings of Syncrude Canada Ltd. in Alberta. In 2005, Titanium Corp. used its pilot facility to optimize the recovery of heavy minerals and

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improve product quality. At yearend, the company began a drill core analysis program to quantify the heavy-mineral resource in the oil sands project (Titanium Corp., Inc., 2006§). In August, the company began operating a 12-metric-ton-per-hour portable wet plant that was connected to the oil tailings pipeline. This was the first time that the company had processed live tailings feedstock; earlier tests used sands from the tailing pond area as feedstock (Industrial Minerals, 2005a).

China.—In 2005, China's tremendous industrial demand continued to influence the global titanium industry. According to one industry report, China's demand for feedstocks was more than 1.5 Mt, a significant increase from demand in 2004. China's production of titanium sponge nearly doubled to reach an estimated 9,500 t in 2005 from 4,810 t in 2004 (Mineral Sands Report, 2006c).

Chinese TiO_2 pigment production is primarily based on a large number of sulfate-route plants, each with capacity of 20,000 t/yr or less. Following a 24% growth from 2003 to 2004, China's production of TiO_2 pigment increased to 574 Mt, another 24% increase (Mineral Sands Report, 2006b).

In November, DuPont and the city of Dongying signed a project agreement to construct a TiO_2 plant. Once relevant government approvals are received, the new TiO_2 plant was expected to represent a total investment at Dongying of more than $1 billion. The plant will be wholly owned by DuPont and will be the company's largest single investment project outside the United States. With a planned completion date of 2010, the plant will have an initial capacity of 200,000 t/yr of TiO_2 and will employ approximately 350 workers (E.I. DuPont de Nemours & Co. Inc., 2005§).

In October, Zhonghe Huayuan Titanium Dioxide Co. Ltd. commissioned is third 16,000-t/yr production line, bringing the company's total TiO_2 pigment capacity to 48,000 t/yr. The plant produces rutile-grade pigment (Mineral Sands Report, 2006c).

Fushun Aluminum Plant in Liaoning Province is planning a new plant to produce titanium sponge that was scheduled to be completed by 2010. The new plant was expected to increase the company's capacity to 10,000 t/yr (Zhao, 2005). An initial expansion of the plant's capacity to 5,000 t/yr was announced in 2004.

In November, Timet entered into a joint venture with Xi'an Baotimet Valinox Tubes Co. Ltd. (BAOTIMET) to produce welded titanium tubing in Xi'an. BAOTIMET's production was expected to begin in early 2007 (Titanium Metals Corp., 2006§).

Gambia, The.—Carnegie Corp. Ltd. completed a trial dredge program at the Sanyang heavy-mineral sands deposit. In 2004, the company completed an environmental impact assessment and received approval for its environmental management plan. At yearend 2005, the company was waiting for the approval of the mining lease (Carnegie Corp. Ltd., 2005§). The project is a joint venture with Astron Ltd. and could yield ilmenite, rutile, and zircon as products.

Japan.—According to the Japan Titanium Society, Japan's shipments of titanium sponge in 2005 were 30,600 t, a 16% increase compared with shipments in 2004. Mill product shipments were 18,100 t, a 4% increase from those in 2004 (Roskill's Letter from Japan, 2006b).

Toho Titanium Co. Ltd. planned to increase production of titanium sponge and titanium ingot. By installing a new electron beam furnace, Toho planned to increase ingot production capacity to 16,000 t/yr from 7,000 t/yr by 2008. The furnace will use 5,000 t/yr of scrap and 11,000 t/yr of sponge as ingot feedstock. Production capacity for sponge at the company's Chigasaki plant was expected to increase to 22,000 t/yr by 2011 from the 2005 level of 15,000 t/yr (Roskill's Letter from Japan, 2005). The company had completed a sponge capacity expansion in 2005 to 15,000 t/yr. Sumitomo Titanium Corp. planned to increase sponge production capacity to 24,000 t/yr from 18,000 t/yr by 2006 (Mineral Sands Report, 2005a).

In 2005, TiO_2 pigment production in Japan was estimated to be 260,000 t, a 2% increase from that in 2004. Paint (46%), pigments (22%), plastics (11%), and paper (9%) were the leading consuming industries in the country (Roskill's Letter from Japan, 2006a).

Kenya.—Tiomin Resources Inc. continued the development of its Kwale heavy-mineral sands project located 40 kilometers south of Mombasa. In 2005, Tiomin was pursuing project financing and announced it had secured sales agreements with two Chinese firms for future output from the mine. The construction phase of the project was expected to begin in 2006. When completed, the project was expected to produce about 330,000 t/yr of ilmenite, 75,000 t/yr of rutile, and 40,000 t/yr of zircon (Tiomin Resources Inc., 2005§).

Madagascar.—In August, Rio Tinto announced the approval to fund the development of the Fort Dauphin mineral sands project. The project was being developed by QIT Madagascar Minerals (QMM) [a Malagasy subsidiary of Rio Tinto (80%) and the Government of Madagascar (20%)]. Part of the project requires the construction of a deep sea port funded by public and private interests. Mine production was expected to reach 750,000 t/yr of ilmenite and 25,000 t/yr of zircon. Mining startup was scheduled for 2008. The mine life could extend for 40 years (Rio Tinto plc, 2005§).

Mozambique.—At yearend, Kenmare Resources plc. was midway through the construction phase of its Moma heavy-mineral sands project. Commissioning of the wet and dry separation plants was expected by yearend 2006. Production capacity from the mine was expected to reach 701,000 t/yr of ilmenite, 17,000 t/yr of rutile, and 60,000 t/yr of zircon (Kenmare Resources plc., 2006§).

In March, BHP Billiton Ltd. acquired Australia-based WMC Resources Ltd. The acquisition brought BHP's interest in the Corridor Sands project in southern Mozambique to 90%. In 2005, BHP was reviewing and updating previously conducted feasibility studies prior to making a decision whether to move into the feasibility phase during 2006. BHP also held a 100% interest in the TiGen heavy-minerals project in Moebase. A prefeasibility study was completed for the TiGen project, and market studies were being examined to determine when the project should move into the feasibility phase (BHP Billiton plc, 2005§).

Poland.—In July, Zakłady Chemiczne Police S.A. completed an initial public offering that raised $46.2 million. The company also awarded a contract for the first phase of upgrading its pigment production facilities. By mid-2008, capacity at the TiO_2 pigment plant was expected to increase to 65,000 t/yr from 40,000 t/yr (Mineral Sands Report, 2005b).

Russia.—United Kingdom-based Aricom plc was developing the Kuranakh ilmenite and iron ore deposit in the Amur region,

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where it expects to start production in late 2007. Production from Kuranakh was expected to be 240,000 t/yr of ilmenite concentrate and a minimum of 660,000 t/yr of iron ore in the form of titanomagnetite concentrate. Aricom entered into conditional offtake agreements in January with China National Gold Corp. that would supply a total of at least 3.3 Mt titanomagnetite concentrate during 5 years and at least 360,000 t of ilmenite concentrate during 1½ years to the Chinese company once production begins. A definitive feasibility study by Vnipiprom Technologiya for mine development was expected to be completed in the first quarter of 2006. Aricom continued to examine options to develop a TiO_2 processing plant (Aricom plc, 2006§).

GMK Norilsk Nickel's plans to mine titanium have run into a serious obstacle because the ores in the company's titanium deposits are radioactive. The technology for purifying the ores would add significantly to the cost of the project; therefore, Norilsk Nickel is unlikely to be able to start developing these deposits in 2006 as planned. Several years ago, Norilsk Nickel acquired licenses for subsurface development at two titanium ore deposits—Yugo-vostochnaya Gremyakha (Murmansk Region, ilmenite-magnetite ore) and Tsentralnoe (Tambov Region, titanium-zirconium ore). The company had planned to mine raw materials for the production of TiO_2 (Kommersant, 2005§).

Senegal.—Mineral Deposits Ltd. (MDL) made plans to relocate its Australia-based dredge and wet concentration plant to its Grande Côte heavy-mineral sands project. The project is located within the Senegal-Mauritania Basin along the northwestern coast of Senegal, south of St. Louis. MDL hoped to commence production in 2007 with a mine capacity of about 75,000 t/yr of zircon and 14,000 t/yr of leucoxene (Mineral Deposits Ltd., 2005§).

Sierra Leone.—In March, the President of Sierra Leone announced the reopening of Sierra Rutile Ltd. mining operation in Moyamba. The operation has been idle since 1995 when civil unrest caused the mine to close. At that time, the mine provided about one quarter of the world's production of natural rutile (Sierra Leone, Office of the President, 2005§).

South Africa.—Australia-based Kumba Resources Ltd. acquired the outstanding 40% interest in the heavy-mineral producer Ticor SA. In 2005, Ticor's heavy minerals operation near Empangeni, KwaZulu-Natal Province, produced 377,000 t of ilmenite, an 18% decrease compared with output in 2004; 134,000 t of chloride slag, a 40% increase from that in 2004; and 30,000 t of sulfate slag, a 25% decrease from that in 2004 (Kumba Resources Ltd., 2006§).

Namakwa Sands improved recovery and raised rutile and zircon production at the Namakwa Sands heavy-mineral sands operation near Brand se Baai. In 2005, Namakwa Sands began an expansion project to increase rutile output by 26% and zircon production by 20%. Namakwa Sands is wholly owned by Anglo American plc (Anglo American plc, 2006§).

Vietnam.—Avireco USA LLC established a joint venture with Viet-My Mineral Co. and Mineral Development Co. No. 6 (Lidisaco) (a subsidiary of Vietnam Mineral Resource Department) to construct a TiO_2 plant in Binh Thuan Province. Construction of the plant was expected to begin in 2006, with initial production capacity of 5,000 t/yr, increasing to 10,000 t/yr. The plant was expected to use Altair Nanotechnologies Inc.'s hydrochloride pigment process technology (Industrial Minerals, 2005b). Vietnam also planned to begin embargoing exports of ilmenite, beginning in 2008.

Outlook

During the next decade, mineral development projects currently underway are expected to ensure an adequate supply of titanium mineral feedstock. An abundance of new chloride-grade mineral feedstock projects and increased demand for sulfate-grade mineral feedstock may delay the development of some projects. For the foreseeable future, China will play an important role in the production and consumption of minerals and pigment. China's double-digit expansion in sulfate-route TiO_2 production capacity should stimulate mineral exploration and development of sulfate-grade mineral feedstock in China and throughout the world.

The drop in domestic TiO_2 pigment production caused by Hurricane Katrina in 2005 is expected to be reversed in 2006. Global TiO_2 pigment production in 2006 is expected to increase by 3% compared with that of 2005. Global TiO_2 pigment consumption growth in 2006 is expected to fall at the high end of the long-term growth rate of 2% to 4% per year.

During the next several years, titanium metal producers from around the globe will be increasing titanium sponge capacity significantly through the expansion of existing facilities in China, Japan, and Russia and the addition of new operations in China and the United States. Numerous government and private industry programs are working to commercialize lower cost methods for producing titanium metal. At least one of these methods should reach commercialization during the next 2 or 3 years. By 2008, domestic and global sponge capacities are expected to reach 31,000 t/yr and 142,000 t/yr, respectively. Growth in commercial aircraft and defense applications is expected to drive demand for titanium metal over the long term.

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TABLE 1
SALIENT TITANIUM STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Ilmenite and titaniferous slag:						
Imports for consumption	metric tons	1,060,000	840,000	804,000	701,000	822,000
Consumption[2]	do.	1,180,000	1,300,000	1,300,000	1,480,000	1,290,000 e
Rutile concentrate, natural and synthetic:						
Imports for consumption	do.	325,000	390,000	427,000	360,000	366,000
Consumption	do.	483,000	487,000	489,000	445,000	424,000 e
Sponge metal:						
Imports for consumption	do.	13,300	10,700	9,590	11,900	15,800
Consumption	do.	26,200	17,300	17,100	21,200	26,100
Price, year-end[3]	dollars per pound	3.58	3.64	2.72-3.95	3.55-6.44	3.46-12.22
Titanium dioxide pigment:						
Production	metric tons	1,330,000	1,410,000	1,420,000	1,540,000	1,310,000
Imports for consumption	do.	209,000	231,000	240,000	264,000	341,000
Consumption, apparent	do.	1,100,000 [4]	1,110,000 [4]	1,070,000 [4]	1,170,000 [5]	1,130,000 [5]
Price, December 31:						
Anatase	dollars per pound	0.92-0.94	0.85-0.95	0.85-0.95	0.90-0.95	0.95-1.00
Rutile	do.	1.00-1.09	0.85-0.95	0.85-0.90	0.90-0.95	0.95-1.00
World, production:						
Ilmenite concentrate[6]	metric tons	5,130,000 r	5,470,000 r	5,720,000 r	5,640,000	5,840,000
Rutile concentrate, natural[7]	do.	421,000	446,000	361,000	353,000	369,000
Titaniferous slag	do.	2,040,000	1,870,000	1,880,000	1,880,000 r	1,880,000 e

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits; except prices.

[2]Excludes consumption used to produce synthetic rutile.

[3]Landed duty-paid unit based on U.S. imports for consumption.

[4]Production plus imports minus exports plus stock decrease or minus stock increase.

[5]Production plus imports minus exports. Excludes stock changes.

[6]Includes U.S. production of ilmenite, leucoxene, and rutile rounded to one significant digit to avoid disclosing company proprietary data.

[7]U.S. production of rutile included with ilmenite to avoid disclosing company proprietary data.

TABLE 2
U.S. TITANIUM METAL PRODUCTION CAPACITY IN 2005[1, 2]

(Metric tons per year)

Company	Plant location	Yearend capacity	
		Sponge	Ingot[3]
Allvac (Allegheny Technologies Inc.)	Albany, OR	--	10,900
Do.	Monroe, NC	--	11,800
Do.	Richland, WA	--	10,000
Alta Group (Honeywell International Inc.)	Salt Lake City, UT	340	--
Howmet Corp. (Alcoa Inc.)	Whitehall, MI	--	3,200
RMI Titanium Co. (RTI International Metals, Inc.)	Niles, OH	--	16,300
Titanium Metals Corp.	Henderson, NV	8,600	12,300
Do.	Morgantown, PA	--	20,000
Do.	Vallejo, CA	--	800
Total		8,940	85,300

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Estimated operating capacity based on 7-day-per-week full production.

[3]Includes electron-beam, plasma, and vacuum-arc-remelting capacity.

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TABLE 3

COMPONENTS OF U.S. TITANIUM METAL SUPPLY AND DEMAND[1]

(Metric tons)

Component	2004	2005
Production:		
Ingot	41,400	48,100
Mill products	26,900 r	30,900
Exports:		
Sponge	2,410	1,910
Waste and scrap	9,760 r	20,600
Other unwrought	1,940 [2]	2,540 [3]
Wrought products and castings[4]	8,300	10,800
Total	22,400	35,800
Imports:		
Sponge	11,900	15,800
Waste and scrap	8,830	12,400
Other unwrought[5]	2,640	3,910
Wrought products and castings	3,590	3,660
Total	26,900	35,800
Stocks, yearend:		
Government, sponge (total inventory)	2,510	--
Industry:		
Sponge	7,660	4,330
Scrap	7,030	6,900
Ingot	3,040	3,270
Consumption, reported:		
Sponge	21,200	26,100
Scrap	18,300 r	25,700
Ingot	34,400	40,100
Shipments:		
Ingot (net shipments)	8,300	9,820
Mill products (net shipments):		
Forging and extrusion billet	6,360	8,110
Plate, sheet, strip	7,940	9,970
Rod, bar, fastener stock, wire	4,570	5,160
Other[6]	196	587
Total	19,100	23,800
Castings (shipments)	W	W
Receipts, scrap:		
Home	7,730	5,490
Purchased	16,500	15,200

rRevised. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes billet, bloom, ingot, powder, sheet bar, slab, and other.

[3]Includes ingot, powder, and other. Billet, bloom, sheet bar and slab classified as wright in 2005.

[4]Billet, bloom, sheet bar, and slab classified as wrought in 2005.

[5]Includes ingot, powder, and other.

[6]Data for pipe, tube, and other have been combined to avoid disclosing company proprietary data.

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TABLE 4

CAPACITIES OF U.S. TITANIUM DIOXIDE PIGMENT PLANTS ON DECEMBER 31, 2005[1, 2, 3]

(Metric tons per year)

Company	Plant location	Capacity[4]
E.I. du Pont de Nemours & Co. Inc.	De Lisle, MS[5]	--
Do.	Edgemoor, DE	154,000
Do.	New Johnsonville, TN	380,000
Tronox Inc.	Savannah, GA[4]	110,000
Do.	Hamilton, MS	225,000
Louisiana Pigment Co. LP	Lake Charles, LA	146,000
Millennium Inorganic Chemicals Inc.	Ashtabula, OH	220,000
Do.	Baltimore, MD	50,000
Total		1,290,000

-- Zero.

[1]Estimated operating capacity based on 7-day-per-week full production.

[2]Table does not include TOR Minerals International's Corpus Christi, TX, production capacity of about 26,400 metric tons per year (t/yr) of buff that is produced by refining and fine grinding of synthetic rutile.

[3]Data are rounded to no more than three significant digits; may not add to totals shown.

[4]All plants use the chloride process to manufacture TiO_2 pigment.

[5]The 300,000-t/yr De Lisle plant was badly damaged by a hurricane in September 2005. At yearend, the plant was being reconstructed.

TABLE 5

COMPONENTS OF U.S. TITANIUM DIOXIDE PIGMENT SUPPLY AND DEMAND[1]

		2004		2005	
		Gross weight	TiO_2 content	Gross weight	TiO_2 content
Production[2]	metric tons	1,540,000	1,440,000 e	1,310,000	1,220,000 e
Shipments:[3]					
Quantity	do.	1,700,000	1,600,000 e	1,420,000	1,220,000 e
Value	thousands	$3,190,000	XX	$3,110,000	XX
Exports	metric tons	635,000	597,000 e	524,000	493,000 e
Imports for consumption	do.	264,000	248,000 e	341,000	321,000 e
Consumption, apparent[e, 4]	do.	1,170,000	1,090,000	1,130,000	1,050,000

eEstimated. XX Not applicable.

[1]Data are rounded to no more than three significant digits.

[2]Excludes production of buff pigment.

[3]Includes interplant transfers.

[4]Production plus imports minus exports. Excludes stock changes.

Sources: U.S. Census Bureau and U.S. Geological Survey.

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TABLE 6
U.S. CONSUMPTION OF TITANIUM CONCENTRATE[1]

(Metric tons)

	2004		2005[e]	
	Gross weight	TiO_2 content	Gross weight	TiO_2 content
Ilmenite and titaniferous slag:[2]				
Pigment	1,460,000	NA	1,260,000	NA
Miscellaneous[3]	19,300	NA	34,000	NA
Total	1,480,000	1,080,000	1,290,000	994,000
Rutile, natural and synthetic:				
Pigment	418,000	NA	394,000	NA
Miscellaneous[3]	26,700	NA	30,000	NA
Total	445,000	414,000	424,000	394,000
Total concentrate:				
Pigment	1,880,000	NA	1,650,000	NA
Miscellaneous[3]	45,900	NA	64,000	NA
Total	1,920,000	1,490,000	1,720,000	1,390,000

[e]Estimated. NA Not available.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes a mixed product containing rutile, leucoxene, and altered ilmenite.

[3]Includes alloys, carbide, ceramics, chemicals, glass fibers, titanium metal, and welding-rod coatings and fluxes.

TABLE 7
U.S. CONSUMPTION OF TITANIUM IN STEEL AND OTHER ALLOYS[1, 2]

(Metric tons)

	2004	2005
Steel:		
Carbon steel	4,180	4,300
Stainless and heat-resisting steel	3,130	3,370
Other alloy steel[3]	1,420	472
Total steel	8,740	8,130
Superalloys	628	1,310
Alloys, other than above	785 [r]	1,460
Miscellaneous and unspecified	53 [r]	54
Grand total	10,200	11,000

[r]Revised.

[1]Includes ferrotitanium, scrap, sponge, and other titanium additives.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Includes high-strength low-alloy and tool steel.

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TABLE 8
U.S. DISTRIBUTION OF TITANIUM PIGMENT SHIPMENTS, TITANIUM DIOXIDE CONTENT, BY INDUSTRY[1]

(Percent)

Industry	2004	2005
Paint, varnish, lacquer	53.6	62.7
Paper	16.0	12.1
Plastics[2]	27.2	24.4
Other[3]	3.2	0.8
Total	100.0	100.0

[1]Excludes exports.
[2]Includes rubber.
[3]Includes agricultural, building materials, ceramics, coated fabrics and textiles, cosmetics, food, paper, and printing ink. Also includes shipments to distributors.

TABLE 9
U.S. STOCKS OF TITANIUM CONCENTRATES, DECEMBER 31[1, 2]

(Metric tons)

	2004		2005[e]	
	Gross weight	TiO_2 content	Gross weight	TiO_2 content
Ilmenite and titaniferous slag	416,000	299,000	NA	NA
Rutile, natural and synthetic	75,400	70,000	NA	NA

[e]Estimated. NA Not available.
[1]Data are rounded to no more than three significant digits.
[2]Consumer stocks.

TABLE 10
PUBLISHED PRICES OF TITANIUM PRODUCTS

		2004	2005
Concentrate:			
Ilmenite, free on board (f.o.b.) Australian ports[1]	dollars per metric ton	72-90	75-85
Rutile, bagged, f.o.b. Australian ports[1]	do.	550-650	550-650
Rutile, bulk, f.o.b. Australian ports[1]	do.	430-480	460-480
Titaniferous slag, 80% to 95% TiO_2[2]	do.	347-466	390-555
Metal:			
Sponge[2]	dollars per pound	3.55-6.44	3.46-12.22
Scrap, turnings, unproccessed[3]	do.	3.80-4.00	4.85-5.15
Ferrotitanium, 70% Ti[3]	do.	6.35-6.45	8.50-9.50
Pigment:			
TiO_2 pigment, f.o.b. U.S. plants, anatase[4]	do.	0.90-0.95	0.95-1.00
TiO_2 pigment, f.o.b. U.S. plants, rutile[4]	do.	0.90-0.95	0.95-1.00

[1]Source: Industral Minerals.
[2]Landed duty-paid unit value based on U.S. imports for consumption.
[3]Source: Platts Metals Week.
[4]Source: Chemical Market Reporter.

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TABLE 11
U.S. EXPORTS OF TITANIUM BY CLASS[1]

Class	HTS[2]	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Metal:					
Sponge	8108.30.0000	2,410	$16,800	1,910	$19,800
Scrap		9,760 r	56,000 r	20,600	91,400
Unwrought:					
Billet	8108.20.0045, 8108.90.6010 r	179	4,800	392	18,900
Bloom, sheet bar, slab	8108.20.0060, 8108.90.6020 r	375	7,490	613	14,300
Ingot	8108.20.0030	951	14,400	1,720	32,600
Other	8108.20.0090	430	7,090	820	17,200
Wrought:					
Bar, rod, profile, wire	8108.90.6030, 8108.90.6031 r	3,310	112,000	3,460	174,000
Other	8108.90.8000	4,990	191,000	6,350	288,000
Total metal		22,400	409,000	35,800	656,000
Ferrotitanium and ferrosilicon titanium	7202.91.0000	2,790	7,690	3,630	21,300
Ores and concentrates	2614.00.0000	8,690	3,370	20,900	8,930
Pigment:					
80% or more titanium dioxide pigment	3206.11.0000	576,000	968,000	486,000	955,000
Other titanium dioxide pigment	3206.19.0000	36,900	81,900	24,000	75,900
Unfinished titanium dioxide[3]	2823.00.0000	22,000	35,700	14,500	30,600
Total		635,000	1,090,000	524,000	1,060,000

rRevised.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States.

[3]Unmixed and not surface treated.

Source: U.S. Census Bureau.

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TABLE 12

U.S. IMPORTS FOR CONSUMPTION OF TITANIUM CONCENTRATE, BY COUNTRY[1]

Concentrate and country	HTS[2]	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Ilmenite:	2614.00.6020				
Australia		120,000	$16,700	135,000	$18,700
South Africa		26,700 [3]	11,700 [3]	--	--
Ukraine		70,000	9,770	19,000	1,670
Vietnam		27,000	2,750	--	--
Total		244,000	40,900	154,000	20,400
Titaniferous slag:	2620.99.5000				
Canada		122,000	56,600	168,000	65,400
South Africa		335,000	135,000	472,000	178,000
Other		97	31	27,000 [3]	10,500 [3]
Total		457,000	192,000	667,000	254,000
Rutile, natural:	2614.00.6040				
Australia		57,100	32,900	35,400	14,600
South Africa		147,000	63,200	137,000	63,200
Ukraine		684	428	5,440	2,510
Other		10,900	3,420	5,970	2,510
Total		216,000	99,900	184,000	83,800
Rutile, synthetic:	2614.00.3000				
Australia		138,000	62,300	158,000	64,100
Malaysia		5,440	2,390	14,300	6,190
Other		78 [r]	71 [r]	9,170 [3]	3,890 [3]
Total		144,000	64,800	182,000	74,200
Titaniferous iron ore, Canada[4]	2614.00.6040	68,700	3,650	61,100	3,560

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States.

[3]All or part of these data have been referred to the U.S. Census Bureau for verification.

[4]Includes materials consumed for purposes other than production of titanium commodities, principally heavy aggregate and steel-furnace flux. Titaniferous iron ore from Canada is classified as ilmenite under the HTS.

Source: U.S. Census Bureau. Data adjusted by the U.S. Geological Survey.

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TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF TITANIUM METAL, BY CLASS AND COUNTRY[1]

Class and country	HTS[2]	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Waste and scrap:	8108.30.0000				
Canada		835	$4,690	905	$7,980
France		941	5,190	2,080	33,800
Germany		1,620	13,300	1,640	29,300
Israel		268	1,780	341	4,670
Japan		2,340	12,400	3,010	33,900
Taiwan		641	4,240	637	10,500
United Kingdom		1,210	6,480	2,060	19,700
Other		972	5,520	--	--
Total		8,830	53,600	12,400	162,000
Unwrought:					
Sponge:	8108.20.0010				
Japan		4,600	32,100	6,200	54,900
Kazakhstan[e]		5,670	38,000	8,390	51,400
Russia		1,380	8,180	977	7,140
Ukraine		37	310	239	5,640
Other		168 [r]	1,280	47	648
Total		11,900	79,900 [r]	15,800	120,000
Ingot:	8108.20.0030				
France		--	--	112	4,010
Germany		271	3,320	332	6,720
Russia		1,150	10,300	1,920	26,500
Other		115	1,150	83	1,490
Total		1,530	14,800	2,450	38,700
Powder:	8108.20.0015				
China		107	1,130	86	1,830
Other		35	1,710	40	2,240
Total		142	2,840	126	4,060
Other:	8108.20.0091				
France		271	2,770	238	4,080
Japan		349	2,710	752	12,600
United Kingdom		181	1,930	180	4,330
Other		158	931	164	1,920
Total		959	8,350	1,330	22,900
Wrought products and castings:[3]	8108.90.3030, 8108.90.3060, 8108.90.6010, 8108.90.6020, 8108.90.6030, 8108.90.6031, 8108.90.6045, 8108.90.6060, 8108.90.6075				
Canada		76	3,090	87	4,750
China		49	1,990	215	8,480
Italy		92	2,700	94	3,890
Japan		456	14,600	390	14,700
Russia		2,470	42,900	2,300	47,100
Sweden		78	2,130	71	2,260
United Kingdom		160	13,700	241	12,200
Other		160 [r]	10,400 [r]	264	18,100
Total		3,540	91,500	3,660	111,000
Ferrotitanium and ferrosilicon titanium	7202.91.0000	6,940	21,200	16,900	76,700

[e]Estimated. [r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States.

[3]Includes bar, billet, bloom, castings, foil, pipe, plate, profile, rod, sheet, sheet bar, slab, strip, tube, wire, and other.

Source: U.S. Census Bureau.

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TABLE 14

U.S. IMPORTS FOR CONSUMPTION OF TITANIUM PIGMENT, BY COUNTRY[1]

Country	HTS[2]	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
80% or more titanium dioxide pigment:	3206.11.0000				
Australia		3,360	$5,480	3,620	$6,380
Belgium		7,340	10,900	9,990	18,000
Canada		71,800	115,000	73,000	141,000
China		9,190	11,500	29,800	39,600
Finland		9,700	17,700	14,000	27,400
France		4,680	6,900	7,060	11,100
Germany		13,200	23,700	17,600	35,200
Italy		10,100	13,600	9,460	14,700
Japan		6,790	14,800	6,190	15,800
Korea, Republic of		9,100	10,100	7,360	8,860
Mexico		16,400	25,300	13,800	23,700
Netherlands		5,350	8,570	5,310	11,300
Norway		5,630	8,610	4,010	6,840
Singapore		2,240	3,580	2,030	3,820
Slovenia		2,440 r	3,670 r	3,020	4,780
Spain		8,750	12,600	8,800	13,900
United Kingdom		7,770	11,600	27,400	47,100
Other		5,040 r	8,000 r	6,130	8,700
Total		199,000	312,000	249,000	438,000
Other titanium dioxide:	3206.19.0000				
Canada		1,960	7,900	2,680	11,100
China		1,070	1,630	795	2,120
Finland		178	1,880	274	2,820
Germany		547	1,550	1,220	3,800
India		341	913	491	1,490
Japan		436	5,760	390	5,830
United Kingdom		161	3,270	113	2,270
Other		687 r	3,330 r	644	2,230
Total		5,370	26,200	6,600	31,600
Unfinished titanium dioxide:[3]	2328.00.0000				
Belgium		--	--	1,560	3,080
Brazil		88	127	2,030	2,590
Canada		10	37	28,600	14,300
China		10,800	11,600	15,700	21,000
Czech Republic		5,350	8,220	7,810	13,100
France		17,400	24,300	17,100	25,700
Germany		9,980	18,500	5,910	13,000
Korea, Republic of		424	521	1,680	2,320
Poland		580	931	752	1,250
Other		14,600 r	10,500 r	4,720	11,300
Total		59,300	74,800	85,800	108,000
Grand total		264,000	413,000	341,000	578,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Harmonized Tariff Schedule of the United States.

[3]Unmixed and not surface treated.

Source: U.S. Census Bureau.

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TABLE 15

TITANIUM: WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY[1, 2]

(Metric tons)

Concentrate type and country	2001	2002	2003	2004	2005[e]
Ilmenite and leucoxene:[3, 4]					
Australia:					
Ilmenite	2,017,000	1,917,000	2,006,000	1,921,000	2,034,000 [5]
Leucoxene	30,000	39,000	57,000	45,000	55,000 [5]
Brazil[6]	144,644 [r]	177,027	120,160 [r]	133,000 [r]	135,000 [p]
China[e]	300,000	750,000	800,000	840,000	900,000
Egypt[e]	125,000	125,000	125,000	125,000	125,000
India[e]	430,000	460,000	500,000	520,000	550,000
Kazakhstan[e]	40,000	50,000	60,000	60,000	60,000
Malaysia	129,750	106,046	95,148	61,471 [r]	70,000
Norway[e]	750,000	750,000	840,000	860,000	860,000
Ukraine	484,500	512,400	420,500	370,000 [e]	370,000
United States[7]	500,000	400,000	500,000 [e]	500,000 [e]	500,000
Vietnam[e]	180,000	180,000	200,000 [r]	200,000 [r]	180,000
Total[8]	5,130,000 [r]	5,470,000	5,720,000 [r]	5,640,000	5,840,000
Rutile:[4]					
Australia	206,000	218,000	173,000	162,000	177,000 [5]
Brazil[6]	2,270	1,878	2,337	3,000 [r]	3,000 [p]
India[e]	19,000	18,000	18,000	19,000	19,000
South Africa[e]	134,000	138,000	108,000	110,000	110,000
Ukraine[e]	60,000	70,000	60,000	60,000	60,000
United States	(9)	(9)	(9)	(9)	(9)
Total	421,000	446,000	361,000	354,000 [r]	369,000
Titaniferous slag:[e, 10]					
Canada	1,010,000	900,000	873,000	863,000 [r]	860,000 [p]
South Africa	1,025,000	973,000	1,010,000	1,020,000	1,020,000
Total	2,040,000	1,870,000	1,880,000	1,880,000 [r]	1,880,000

[e]Estimated. [p]Preliminary. [r]Revised.

[1]Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 15, 2006.

[3]Ilmenite is also produced in Canada and South Africa, but this output is not included here because most of it is duplicative of output reported under "Titaniferous slag," and the rest is used for purposes other than production of titanium commodities, principally steel furnace flux and heavy aggregate.

[4]Small amounts of titanium minerals were reportedly produced in various countries; information, however, is inadequate to make reliable estimates of output levels.

[5]Reported figure.

[6]Excludes production of unbeneficiated anatase ore.

[7]Includes rutile to avoid disclosing company proprietary data. Rounded to one significant digit.

[8]Includes U.S. production, rounded to one significant digit, of ilmenite, leucoxene, and rutile to avoid disclosing company proprietary data.

[9]Included with ilmenite to avoid disclosing company proprietary data.

[10]Slag is also produced in Kazakhstan, Norway,and Russia, but this output is not included under "Titaniferous slag" to avoid duplicative reporting.

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TUNGSTEN

By Kim B. Shedd

Domestic survey data and tables were prepared by Amy C. Tolcin, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

No U.S. tungsten mine production was reported in 2005. U.S. supply of tungsten raw materials comprised imports, tungsten-bearing scrap, releases from industry stocks, and sales of excess materials from the National Defense Stockpile (NDS). China continued to be the world's leading producer of tungsten concentrates and the leading supplier of U.S. imports of tungsten materials. Tight supplies of tungsten concentrates within China resulted in significant increases in the world prices of ammonium paratungstate, ferrotungsten, and tungsten ore concentrates. U.S. apparent consumption was lower than that for 2004, primarily because of a significant increase in U.S. exports. Salient U.S. tungsten statistics and world tungsten concentrate production for 2005 and the previous 4 years are listed in table 1.

Most data in this report have been rounded to three significant digits. Totals and percentages were calculated from unrounded numbers. Unless otherwise specified, all statistics in this report are in metric tons of contained tungsten. Tungsten prices and many tungsten statistics from other sources are quoted in units of tungsten trioxide (WO_3). The short ton unit, which is used in the United States, is 1% of a short ton (20 pounds), and WO_3 is 79.3% tungsten. A short ton unit of WO_3, therefore, equals 20 pounds of WO_3 and contains 7.19 kilograms (kg) (15.86 pounds) of tungsten. The metric ton unit, which is used in most other countries, is 1% of a metric ton (10 kg). A metric ton unit of WO_3, therefore, equals 10 kg of WO_3 and contains 7.93 kg (17.48 pounds) of tungsten.

Tungsten is a whitish-gray metal with many unique properties and a wide variety of commercial, industrial, and military applications. The leading use is as tungsten carbide in cemented carbides, which are wear-resistant materials used by the construction, metalworking, mining, and oil and gas drilling industries. Tungsten alloy and pure tungsten metal contacts, electrodes, and wires are used in electrical, electronic, heating, lighting, and welding applications. Tungsten is also used to make heavy-metal alloys for armaments, heat sinks, radiation shielding, and weights and counterweights; superalloys for turbine blades; tool steels; and wear-resistant alloy parts and coatings. Tungsten alloys and composites are used as a substitute for lead in bullets and shot. Tungsten chemicals are used to make catalysts, corrosion-resistant coatings, dyes and pigments, fire-resistant compounds, lubricants, phosphors, and semiconductors.

Legislation and Government Programs

The Defense National Stockpile Center (DNSC), U.S. Department of Defense, sold tungsten materials from the NDS under two formats—negotiated sales and a strategic supply alliance (SSA). Awards from negotiated sales were made in January and May for ores and concentrates, in March and November for ferrotungsten, and in September for metal powder and fabricated materials. The November award of ferrotungsten depleted the NDS of that material. The DNSC awarded approximately 248 metric tons (t) of tungsten in ores and concentrates as SSA sales during fiscal year 2005 (October 1, 2004, through September 30, 2005); additional ores and concentrates were sold under the SSA format during the quarter ending December 31, 2005 (Defense National Stockpile Center, 2005; U.S. Department of Defense, 2006, p. 61-62).

During fiscal year 2005, 2,520 t of contained tungsten was sold. By the end of the fiscal year, 33 t of tungsten metal powder and 194 t of tungsten contained in ores and concentrates had been sold, but not shipped, from the stockpile (U.S. Department of Defense, 2006, p. 11, 57).

During the calendar year, 2,750 t of tungsten contained in ferrotungsten, tungsten metal powder, and tungsten ores and concentrates was sold. The quantities of tungsten materials remaining in the stockpile at the end of the calendar year, including those committed for sale and pending shipment, are listed in tables 1 and 2.

The Annual Materials Plan for fiscal year 2005, which represented the maximum quantities of tungsten materials that could be sold, is listed in table 2. The quantity for tungsten ores and concentrates available for sale during fiscal year 2006 (October 1, 2005, through September 30, 2006) was increased to 3,630 t (8 million pounds) of contained tungsten; the quantities for tungsten metal powder and ferrotungsten were unchanged from those for fiscal year 2005 (U.S. Department of Defense, 2006, p. 7, 9, 25).

The U.S. Fish and Wildlife Service (FWS) granted final approval for use of an iron-tungsten-nickel shot product for hunting waterfowl and coots. Approval of this product, which contained 62% iron, 25% tungsten, and 13% nickel, brought the number of FWS-approved tungsten-base shot products to nine. The other eight products were tungsten bronze, tungsten-iron containing 40% tungsten, tungsten-iron containing 22% tungsten, tungsten matrix (a tungsten-polymer composite), tungsten-nickel-iron, tungsten polymer, tungsten-tin-bismuth, and tungsten-tin-iron-nickel (U.S. Fish and Wildlife Service, 2005).

The Department of Health and Human Services (HHS) Agency for Toxic Substances and Disease Registry published a final toxicological profile on tungsten. In addition to presenting available information on the health effects of tungsten and tungsten compounds, the profile also identified ongoing research and areas for possible future study (Agency for Toxic Substances and Disease Registry, 2005§[1]).

The U.S. Environmental Protection Agency (EPA) recommended that two tungsten oxide compounds be added to the Toxic Substances Control Act's Preliminary Assessment Information Reporting (PAIR) Program. The oxides are in addition to 20 tungsten compounds that were added in 2003.

[1]References that include a section mark (§) are found in the Internet References Cited section.

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Tungsten compounds were added to the PAIR program because limited data were available to assess the potential long-term adverse health effects of tungsten exposure. The program requires producers and importers of listed materials to report production, importation, and exposure data to the EPA (U.S. Environmental Protection Agency, 2004, 2005).

Production

Domestic production statistics for tungsten are based on data collected by the U.S. Geological Survey (USGS) by means of two separate voluntary surveys. Statistics that result from these surveys are listed in tables 1 and 3. The annual "Tungsten Ore and Concentrate Survey" covered the production, purchases, disposition, and stocks of tungsten ores and concentrates. No tungsten mine output was reported for the United States in 2005. The monthly "Tungsten Concentrate and Tungsten Products Survey" canvassed companies that produced tungsten carbide powder, tungsten chemicals, and/or tungsten metal powder from ammonium paratungstate, tungsten-bearing scrap, and tungsten concentrate. Major U.S. processors of tungsten materials operating in 2005 included Allegheny Technologies Inc.'s Metalworking Products business, Huntsville, AL; Buffalo Tungsten Inc., Depew, NY; General Electric Co., Euclid, OH; Kennametal Inc., Latrobe, PA, and Fallon, NV; and Osram Sylvania, Inc., Towanda, PA.

In 2005, U.S. processors consumed more ammonium paratungstate and tungsten scrap and less tungsten concentrates than they did in 2004. Domestic production of ammonium paratungstate was higher than that of 2004. Net production of tungsten metal powder and tungsten carbide powder increased by 6% in 2005 compared with that of 2004 (table 3).

Consumption

U.S. apparent consumption of all tungsten materials, as calculated from net imports, primary and secondary production, and changes in Government and industry stock levels, was 11,600 t in 2005, which was 7% lower than the 2004 apparent consumption of 12,600 t. In 2005, total imports, scrap consumption, and NDS shipments were greater than those of 2004. The apparent decrease in consumption was primarily because of higher exports in 2005 than those in 2004.

Statistics on consumption of tungsten in end-use applications by U.S. metal consumers were developed from the voluntary "Consolidated Consumers Survey." For this survey, approximately 65 tungsten consumers were canvassed on a monthly or annual basis. Reported consumption and stock data in tables 1 and 4 include estimates to account for nonrespondents.

Total U.S. reported consumption of tungsten materials to make end-use products in 2005 was slightly lower than that of 2004. Steelmakers and superalloy melters used more tungsten in 2005 than in 2004, producers of other alloys and mill products for lighting and other industries used less, and producers of cemented carbides and chemicals used about the same amount of tungsten in each of the 2 years. Compared with 2004, in 2005, U.S. industry consumed more ferrotungsten and tungsten scrap; less tungsten carbide powder and tungsten metal powder; and approximately the same amount of tungsten chemicals.

Weekly reports of the number of operating drilling rigs give an indication of the demand for tungsten carbide in the form of cemented carbide components used by industry to explore for or to produce oil and natural gas. The number of rigs that operated in the United States continued to trend upward during 2005. The average number of operating rigs in the United States was 1,383, 16% higher than the average 1,192 operating rigs in 2004 (Baker Hughes Inc., undated§).

In 2005, total consumption of tungsten scrap by U.S. processors and consumers was 4,640 t of contained tungsten, which was 16% more than the 4,000 t consumed in 2004.

Prices

During the first half of 2005, inadequate supplies of tungsten concentrates within China, combined with increased demand for tungsten materials in China and elsewhere and a reduction in Chinese export tax rebates, resulted in steep increases in the world prices of tungsten concentrates, ammonium paratungstate, and ferrotungsten. Reasons cited for the tight supply of Chinese concentrates ranged from an actual shortage to market manipulation (Li and Magnowski, 2005). Most prices declined somewhat during the summer months and then increased again beginning in September.

Ammonium paratungstate is the most widely traded primary tungsten material, and as a result, its price has become a reference price for such upstream materials as tungsten ore concentrates and such downstream materials as tungsten metal powder and tungsten carbide powder. Annual average ammonium paratungstate prices in 2005 were more than two and one-half times those of 2004 (table 1). The U.S. ammonium paratungstate price reported by Platts Metals Week began the year at $94 to $98 per short ton unit ($104 to $108 per metric ton unit), more than tripled to $300 to $320 per short ton unit ($331 to $353 per metric ton unit) by mid-May, fell to $190 to $205 per short ton unit ($209 to $226 per metric ton unit) in mid-August, and then rose to end the year at $250 to $260 per short ton unit ($276 to $287 per metric ton unit). U.S. ammonium paratungstate prices reported by Metal Bulletin followed the same trend, with the lowest prices [$94 to $97 per short ton unit ($104 to $107 per metric ton unit)] at the beginning of the year and the highest prices [$290 to $310 per short ton unit ($320 to $342 per metric ton unit)] in mid-May to early June.

Annual average tungsten ore concentrate prices more than doubled (tables 1 and 5). The U.S. spot tungsten ore concentrate price reported by Platts Metals Week, began the year at $55 to $65 per short ton unit ($61 to $72 per metric ton unit), more than tripled to a high of $190 to $210 per short ton unit ($209 to $231 per metric ton unit) in late May to early June, fell to $110 to $120 per short ton unit ($121 to $132 per metric ton unit) by mid-August, and then rose to end the year at $180 to $200 per short ton unit ($198 to $220 per metric ton unit). The Platts' ferrotungsten price was $12.00 to $13.00 per kilogram of contained tungsten in early January, reached a high of $34.40 to $39.20 per kilogram of contained tungsten in mid-October to early November, and ended the year at $32.00 to $34.00 per kilogram of contained tungsten.

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Foreign Trade

The total tungsten content of U.S. exports was 5,940 t, 58% higher than the 3,770 t exported in 2004. Exports of all materials, except ferrotungsten and wire, increased compared with those of 2004 (tables 6-10).

The total tungsten content of U.S. imports was 11,200 t, 6% higher than the 10,600 t imported in 2004. China, which continued to be the leading supplier of imported tungsten to the United States, provided 42% of all tungsten imports in 2005. In 2005, the total tungsten content of imports from China increased by 3% to 4,730 t from 4,610 t in 2004. The distribution of materials imported from China was as follows: ammonium paratungstate, 38%; tungsten carbide powder, 18%; tungsten oxide, 14%; tungsten metal powder, 13%; ferrotungsten, 7%; tungsten waste and scrap and unwrought tungsten, 4% each; wrought tungsten, 3%; and tungsten ore, minor amounts. Other significant suppliers of tungsten materials were as follows: Germany, with 11% of the total tungsten imports to the United States; Canada, 10%; Portugal, 7%; and Bolivia and Israel, 5% each.

The tungsten contained in U.S. imports of ores and concentrates was 10% lower than that of 2004, primarily as a result of reduced imports from Canada (table 11). In 2005, the leading suppliers of U.S. imports of tungsten ores and concentrates were Portugal (37%), Bolivia (26%), Canada (13%), Rwanda and Thailand (7% each), and Russia (5%).

U.S. imports of ammonium paratungstate decreased by 8% compared with those of 2004 (table 12). China continued to be the dominant supplier, providing 93% of U.S. ammonium paratungstate imports. Trends in imports of other tungsten materials are presented in tables 13-14.

In 2005, U.S. net import reliance as a percentage of apparent consumption was 68%. Net import reliance as a percentage of apparent consumption is used to measure the adequacy of current domestic production to meet U.S. demand. Net import reliance was defined as imports minus exports plus adjustments for Government and industry stock changes. Releases from stocks, including shipments from the NDS, were counted as part of import reliance, regardless of whether they were imported or produced in the United States. Because there was no recorded U.S. mine production in 2005, about 68% of U.S. tungsten supply was from imports and stock releases, and 32% was from scrap materials generated in the United States.

World Industry Structure

Estimated world tungsten mine production increased in 2005, primarily because of the restart of the Cantung Mine in Canada and an increase in estimated production from China (table 15). In addition to mine production and tungsten recovered from scrap, tungsten materials from stockpiles in Japan and the United States contributed to supply in 2005.

World Review

Australia.—Tasmania Mines Ltd. produced limited quantities of scheelite concentrates as a byproduct of mining magnetite from its Kara open pit mine south of Burnie in Tasmania.

King Island Scheelite Ltd. (formerly named GTN Resources Ltd.) studied the feasibility of redeveloping the King Island Scheelite Mine, which operated between 1917 and 1990 at Grassy, King Island, northwest of Tasmania. The company was considering a three-stage development of the mine over a period of more than 30 years. Initial production would be by open pit mining, followed by expanding and deepening the open pit, and ending with the possible development of an underground mining operation below the pit. King Island Scheelite expected to complete the final bankable feasibility study in 2006, negotiate financing and offtake agreements, and complete the permitting process so that the mine could be developed and production could begin in 2007. Future production was forecast to be 2,400 to 3,100 metric tons per year (t/yr) of tungsten contained in concentrates (King Island Scheelite Ltd., 2005, p. 25, 35-36).

Queensland Ores Ltd. began a feasibility study on its Wolfram Camp tungsten-molybdenum project 90 kilometers (km) west of Cairns in Queensland. The company focused on exploring for tungsten-molybdenum mineralization to support an open pit mine (Queensland Ores Ltd., 2006).

Austria.—Wolfram Bergbau und Hütten GmbH Nfg KG produced tungsten concentrates from the Mittersill scheelite mine in the Province of Salzburg. All these concentrates were converted to primary tungsten products at Wolfram Bergbau's Bergla tungsten processing plant in the Province of Steiermark.

Canada.—North American Tungsten Corp. Ltd. completed arrangements with its creditors and emerged from protection under the Canadian Companies' Creditors Arrangement Act. At midyear, the company began the process of reactivating its Cantung Mine and concentrator in Northwest Territories and, in September, made its first shipment of tungsten concentrates. The company worked to improve operations by increasing underground mine development, introducing new equipment and longhole mining methods, and automating some of the milling operations. North American Tungsten modified its milling circuit to produce a single tungsten concentrate with an average grade of 65% WO_3. This was expected to increase the number of potential customers and bring a higher average sales price than the two grades of concentrates formerly produced (North American Tungsten Corp. Ltd., 2005, p. 2, 5, 8; 2006, p. 5-6).

China.—The China Tungsten Industry Association (CTIA) reported that there were 48 ammonium paratungstate producers with a combined capacity of 131,000 t/yr, 69 tungsten metal powder producers with a combined capacity of 53,600 t/yr, 197 cemented carbide producers with a combined capacity of 28,400 t/yr, and 33 producers of tungsten filaments with a combined capacity of 29.56 billion meters in 2005. CTIA production figures for China were as follows: 90,900 t of tungsten concentrate (WO_3), 51,800 t of ammonium paratungstate, 38,100 t of tungsten oxide, 20,600 t of tungsten metal powder, 15,100 t of cemented carbide, 2,482 t of tungsten bar and rod, and 1,093 t of tungsten filament. In 2005, China recycled 8,019 t of tungsten contained in scrap and imported 6,087 t of tungsten ores and concentrates and 4,600 t of tungsten contained in products, excluding cemented carbides. Domestic demand increased by 11.5% to 22,300 t of contained tungsten. China exported 31,150 t of tungsten contained in products, excluding cemented carbides (Beijing Antaike Information Development Co., Ltd., 2006b, p. 3-4).

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In recent years, China's Government has had a program to make full use of its tungsten resources and to try to stabilize world tungsten prices. This program included regulating the production of tungsten concentrates through mine closures and production quotas and regulating tungsten exports by restricting the volumes and types of tungsten materials and products that could be sent out of the country. For 2005, the tungsten concentrate production quota was maintained at 52,000 t (65% WO_3). Two percent of the quota was to be from concentrates recovered from gangue, and the remaining production, by province or autonomous region, was distributed as follows: Jiangxi (58%), Hunan (20%), Guangdong and Yunnan (6% each), Fujian, Guangxi, and Inner Mongolia (2% each), Zhejiang (1%), and Anhui and Qinghai (0.1% each). The 2005 export quota for tungsten materials was set at 16,300 t of contained tungsten. A 13% export tax rebate for ferrotungsten was abolished as of January 1, 2005. Export rebates for other tungsten products were decreased to 8% from 13% as of May 1, 2005, and were to be further reduced to 5% as of January 1, 2006. In addition, to conserve energy, the Government began to take action against the toll production of ferroalloys from imported concentrates, including those of tungsten (Beijing Antaike Information Development Co., Ltd., 2005, p. 13; 2006a, p. 4; China Tungten Industry Association, 2005; Metal Bulletin, 2005; Ryan's Notes, 2005).

India.—Sandvik AB planned to build a new cemented carbide recycling plant adjacent to its existing cobalt recycling plant in Chiplun, south of Mumbai. The new 600-t/yr-capacity plant will process hard cemented carbide scrap collected mainly from Sandvik customers outside of India. All powder produced at the plant will be exported and was expected to replace about one-fourth of the raw materials currently used by the company at plants outside India. The plant was expected to begin operations in mid-2006 (Economic Times, The, 2005§).

Israel.—Metal-Tech Ltd. increased the production capacity of its tungsten processing plant in Ramat Hovav. The plant recycled various types of metal-based wastes to produce tungsten carbide powder, tungsten metal powder, and tungsten oxide (Metal-Tech Ltd., 2006).

Japan.—Japan Oil, Gas and Metals National Corporation (JOGMEC) was the Government agency established to maintain a stable supply of natural resources and energy to Japanese industry. As a result of rising prices, JOGMEC sold 117 t of tungsten concentrates from its rare metals stockpile in June (Japan Oil, Gas and Metals National Corporation, 2006§).

Mongolia.—A joint venture formed between Russian manufacturing and trading company Wolfram Co. (70%) and Mongolian minerals exploration and mining company Kainar Co. Ltd. (30%) began mining the Kyzyl-Tau wolframite deposit in western Mongolia (Wolfram Co., 2006§).

Peru.—In November, Dynacor Mines Inc. acquired Minera Malaga Santolalla S.A.C., which owned the Pasto Bueno tungsten mine approximately 90 km east of the Pacific coast in the Ancash region of Peru. Minera Malaga's assets included two mills for processing ore by gravity methods, two hydroelectric plants and associated water rights, equipment, and a mining camp. The mine began production in 1940, but has had only limited output since the early 1990s. In addition to tungsten, production included copper, lead, silver, and zinc (Dynacor Mines Inc., 2006a; Vector Engineering, Inc., 2006, p. iii, 11).

Portugal.—During the year, Beralt Tin & Wolfram S.A. made improvements to its Panasqueira tungsten mine in east central Portugal. Beralt replaced underground mining equipment with low-profile units, which were expected to increase the mining rate, reduce the quantity of waste rock handled, and improve the grade of ore sent to the processing plant. The company began underground mine development work to access new mining areas and a surface and underground drilling program for mine planning and to investigate potential mineralization elsewhere in the mine. As part of its improvement program, Beralt also planned to add new equipment to the ore processing plant to increase tungsten recovery. In May, Beralt entered into a multiyear contract with Osram for the sale of substantially all of the tungsten concentrate produced from Panasqueira. The contract replaced a previous agreement with Osram that was to expire in April 2006 (Primary Metals Inc., 2006).

Russia.—In recent years, tungsten concentrates have been produced from Primorsky GOK's Vostok-2 Mine and Lermontovskaya Mining Co.'s operation in Primorskiy Kray, from Tyrnyauzsky GOK's operation in the Republic of Kabardino-Balkariya, and from Novoorlovsky GOK in the Aga Buryat Autonomous Okrug. Tyrnyauzsky reportedly nearly ceased production in 2005; Primorsky and Lermontovskaya were also close to shutting down. Novoorlovsky GOK reportedly established a tungsten processing plant in 2005, which was to process ore from the Spokoininskoye tungsten deposit (Interfax International Ltd., 2005a; Interfax Ltd., 2005b).

In the past few years, Russia had increased its capacity to process tungsten-bearing scrap. The country is also a producer of ferrotungsten for domestic use and export (Visser, 2002, p. 7; Schiller, 2004, p. 11).

Spain.—Daytal Resources plc (a joint venture between Cambrian Mining Plc, Tungsten SA Pty. Ltd., and Prehenita S.L) began a feasibility study on the Los Santos tungsten project in the Castilia y Leon region. The Los Santos deposit had a measured and indicated resource of 3.5 million metric tons grading 0.29% WO_3. Daytal was considering open pit mining followed by standard comminution, gravity concentration, and filtration to produce scheelite concentrates beginning in 2008 (Heemskirk Consolidated Ltd., 2006).

Thailand.—SC Mining Co. Ltd. produced high-grade ferberite concentrates from an open pit mine southwest of Chiang Mai in northern Thailand (Black, 2003).

Uzbekistan.—Navoi Mining and Metallurgy Combine and Integra Mining reportedly planned to set up a joint venture to process tailings from the Ingichki tungsten deposit. A feasibility study was initiated on the venture, which was to produce tungsten concentrates for the Uzbek Heat-Resistant and Refractory Metals Plant, as well as for export (Interfax Ltd., 2005c).

Vietnam.—Tiberon Minerals Ltd. of Calgary, Alberta, Canada, completed a final feasibility study on developing the Nui Phao deposit 80 km north-northwest of Hanoi in Thai Nguyen Province. During the year, the Government of Vietnam approved the company's environmental impact assessment and granted a mining license for the project. Tiberon planned to mine the deposit from a single open pit and process the ore by using flotation and gravity methods. The tungsten concentrate was expected to contain an average of 3,718 t/yr of tungsten (4,689 t/yr of WO_3) during a mine life of more than 16 years. Osram agreed to purchase up to 100% of

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Nui Phao's annual average production of tungsten concentrates; any tungsten concentrates not purchased by Osram could be sold to the market by Nui Phao Joint Venture Co. Ltd. (a subsidiary of Tiberon). Bismuth cement and copper and fluorspar concentrates would also be produced. Tiberon hoped to begin commercial production in early 2008 (Tiberon Minerals Ltd., 2006, p. 11-13, 21-23).

Outlook

Demand for tungsten tends to follow general economic conditions. Future consumption of tungsten in cemented carbides, which is the leading end-use sector, will depend on the performance of the following industries: automotive and aircraft production; construction; electronics manufacturing, where cemented carbide microdrills are used on circuit boards; general manufacturing; large equipment manufacturing; mining; and oil and gas drilling. Demand for tungsten is also influenced by changes in government spending for defense applications. In 2002, the consumption of tungsten to produce 5.56-millimeter "green ammunition" for the military was forecast to reach 2,200 to 2,700 t by the year 2006, depending on which ammunition was produced. Since that forecast was made, a significant increase in ammunition requirements and the higher cost of producing the tungsten-base ammunition compared with conventional lead-base ammunition resulted in a restructuring of the green ammunition program to identify a "total cartridge solution" that would lessen environmental impact, perform at least as well or better than the current cartridge, and be cost effective. Future demand for tungsten in green ammunition will depend on the outcome of this research (Payne, 2002, p. 10-11; Metal-Pages, 2005§; U.S. Army Armament Research, Development and Engineering Center, 2005a§, b§).

World tungsten supply will continue to be dominated by Chinese production and exports. Chinese export licenses for 2006 were limited to a total of 15,800 t of all tungsten products, a decrease from the quota of 16,300 t in 2005 (Beijing Antaike Information Development Co., Ltd., 2005, p. 13).

Tungsten prices remained strong during the first half of 2006. As a result of continued high prices and anticipated future growth in demand for tungsten, production from non-Chinese mines was expected to increase. In 2006, Canadian and Portuguese producers planned to increase their output of tungsten concentrates, and Peru's Pasto Bueno Mine began producing concentrates from stockpiled tailings. Production from new (greenfield) mines outside China was not expected before the third quarter of 2007. Numerous additional tungsten mine projects were in the exploration and prefeasibility stages of development (Dynacor Mines Inc., 2006b; King Island Scheelite Ltd., 2006, p. 35).

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TABLE 1
SALIENT TUNGSTEN STATISTICS[1]

(Metric tons of tungsten content and dollars per metric ton unit)

	2001	2002	2003	2004	2005
United States:					
Concentrates:					
Consumption	W	W	W	W	W
Exports	220	94	20	43	52
Imports for consumption	2,680	4,090	4,690	2,310	2,080
Stocks, December 31:					
Consumer	W	W	W	W	W
U.S. Government[2]	31,200 e	30,100	29,400	28,400	26,100
Price:					
U.S. spot quotation[3]	64	55	50	49	146
European[4]	65	38	45	55	123
Ammonium paratungstate:					
Production	W	W	W	W	W
Consumption[5]	9,240	8,860	9,450	8,790	9,530
Stocks, December 31, producer and consumer	W	68	W	W	W

See footnotes at end of table.

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TABLE 1—Continued
SALIENT TUNGSTEN STATISTICS[1]

(Metric tons of tungsten content and dollars per metric ton unit)

	2001	2002	2003	2004	2005
United States—Continued:					
Ammonium paratungstate—Continued:					
Price:					
U.S. free market[6]	99	72	69	92	237
U.S. market[3]	97	73	72	91	240
European free market[6]	89	54	62	84	223
Primary products:					
Net production[7]	10,100	12,400	9,420	7,400	7,810
Consumption[8]	9,090	9,490	9,600	11,200	11,000
Stocks, December 31:					
Producer[9]	698	666	793	787	800
Consumer[8]	729	394	423	406	505
U.S. Government[2]	1,120 e	947	765	685	282
World, production of concentrate	50,800 r	66,100 r	68,200 r	69,400 r	70,100 e

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits.

[2]Defense National Stockpile Center. Includes material committed for sale pending shipment.

[3]Annual average calculated from weekly prices reported by Platts Metals Week.

[4]Annual average calculated from semiweekly prices reported by Metal Bulletin.

[5]Reported by tungsten processors.

[6]Annual average calculated from annual average high and low prices reported by Metal Bulletin.

[7]Includes only tungsten metal powder and tungsten carbide powder.

[8]Includes ammonium paratungstate and other tungsten chemicals, ferrotungsten, tungsten metal powder, tungsten carbide powder, and tungsten scrap.

[9]Data exclude cast and crystalline tungsten carbide powder and chemicals.

TABLE 2
U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE TUNGSTEN STATISTICS IN 2005[1, 2]

(Metric tons of tungsten content)

	Inventory, yearend[3]		Annual	Sales		Inventory decrease[4]	
Material	Fiscal year[5]	Calendar year	Materials Plan[5]	Fiscal year[5]	Calendar year	Fiscal year[5]	Calendar year
Ores and concentrates	26,700	26,100	2,270	2,250	2,350	1,710	2,310
Ferrotungsten	105	--	136	121	254	157	262
Tungsten metal powder	413	282	136	147	147	50	142
Total	27,200	26,300	2,540	2,520	2,750	1,920	2,710

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes stockpile- and nonstockpile-grade materials.

[3]Includes material committed for sale pending shipment.

[4]From previous year.

[5]Twelve-month period ending September 30, 2005.

Source: Defense National Stockpile Center.

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TABLE 3

U.S. NET PRODUCTION AND STOCKS OF TUNGSTEN PRODUCTS[1, 2, 3]

(Metric tons of tungsten content)

	Tungsten metal powder	Tungsten carbide powder	Total
Net production:			
2004	3,020	4,370	7,400
2005	3,150	4,660	7,810
Producer stocks:			
December 31, 2004	438	349	787
December 31, 2005	395	405	800

[1]Net production equals receipts plus gross production less quantity used to make other products in table.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Data for cast and crystalline tungsten carbide powder and tungsten chemicals are withheld to avoid disclosing company proprietary data; not included in "Total."

TABLE 4

U.S. REPORTED CONSUMPTION AND STOCKS OF TUNGSTEN PRODUCTS[1, 2, 3]

(Metric tons of tungsten content)

	2004	2005
Consumption by end use:		
Steels	259	280
Superalloys	W	W
Other alloys[4]	W	W
Cemented carbides[5]	6,020	6,020
Mill products made from metal powder	W	W
Chemical uses	130	130
Total	11,200	11,000
Consumption by form:		
Ferrotungsten	248	250
Tungsten metal powder	W	W
Tungsten carbide powder	6,120	5,930
Tungsten scrap	W	W
Other tungsten materials[6]	130	130
Total	11,200	11,000
Consumer stocks, December 31:		
Ferrotungsten	21	24
Tungsten metal powder	28	27
Tungsten carbide powder	308	394
Tungsten scrap	19	29
Other tungsten materials[6]	30	30
Total	406	505

W Withheld to avoid disclosing company proprietary data; included in "Total."

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Does not include materials used in making primary tungsten products.

[3]Includes estimates.

[4]Includes welding and hard-facing rods and materials, wear- and corrosion-resistant alloys, and nonferrous alloys.

[5]Includes diamond tool matrices, cemented and sintered carbides, and cast carbide dies or parts.

[6]Includes tungsten chemicals.

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TABLE 5
MONTHLY PRICE QUOTATIONS OF TUNGSTEN CONCENTRATES IN 2005

	Metal Bulletin, European market, 65% WO_3 basis, c.i.f.[1, 2]				Platts Metals Week, U.S. spot quotations, 65% WO_3 basis, c.i.f.[1]. U.S. ports, including duty[3]			
	Dollars per metric ton unit			Dollars per short ton unit,	Dollars per short ton unit			Dollars per metric ton unit,
Month	Low	High	Average	average	Low	High	Average	average
January	62	66	64	58	55	65	60	66
February	68	80	74	67	65	80	73	80
March	74	95	85	77	75	85	80	88
April	86	95	91	82	80	100	90	99
May	86	160	123	112	90	210	150	165
June	130	160	145	132	180	210	195	215
July	130	160	145	132	140	180	160	176
August	130	160	145	132	110	140	125	138
September	130	160	145	132	110	155	133	146
October	130	160	145	132	145	155	150	165
November	130	160	145	132	160	210	185	204
December	130	160	145	132	160	200	180	198

[1]Cost, insurance, and freight.

[2]Combined wolframite and scheelite quotations. Low and high prices are reported semiweekly. Monthly averages are arithmetic averages of semiweekly low and high prices. The annual average price per metric ton unit of WO_3 of all semiweekly low and high prices was $123 in 2005. The average equivalent price per short ton unit of WO_3 was $111 in 2005.

[3]Low and high prices are reported weekly. Monthly averages are arithmetic averages of weekly low and high prices. The annual average price per short ton unit of WO_3 of all weekly low and high prices was $132 in 2005. The average equivalent price per metric ton unit of WO_3 was $146 in 2005.

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TABLE 6

U.S. EXPORTS OF TUNGSTEN ORES AND CONCENTRATES, BY COUNTRY[1]

	2004			2005		
	Quantity			Quantity		
Country of destination	Gross weight (metric tons)	Tungsten content[2] (metric tons)	Value (thousands)	Gross weight (metric tons)	Tungsten content[2] (metric tons)	Value (thousands)
Argentina	(3)	(3)	$5	(3)	(3)	$3
Australia	2	1	32	--	--	--
Bulgaria	--	--	--	(3)	(3)	6
Canada	4	2	28	--	--	--
China	17	9	259	63	33	861
France	(3)	(3)	7	(3)	(3)	4
Germany	19	10	159	--	--	--
Hong Kong	--	--	--	(3)	(3)	6
India	(3)	(3)	7	--	--	--
Ireland	--	--	--	(3)	(3)	17
Italy	1	(3)	13	--	--	--
Japan	(3)	(3)	5	(3)	(3)	12
Korea, Republic of	--	--	--	2	1	24
Malaysia	--	--	--	(3)	(3)	3
Mexico	(3)	(3)	5	--	--	--
Netherlands	2	1	35	28	14	552
Philippines	(3)	(3)	3	--	--	--
Singapore	(3)	(3)	3	--	--	--
South Africa	1	1	9	--	--	--
Sweden	18	9	156	--	--	--
Switzerland	--	--	--	(3)	(3)	6
Taiwan	(3)	(3)	4	--	--	--
United Kingdom	18	9	229	7	4	106
Total	83	43	959	102	52	1,600

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Content estimated from reported gross weight.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 7

U.S. EXPORTS OF AMMONIUM PARATUNGSTATE, BY COUNTRY[1]

	2004		2005	
Country of destination	Quantity, tungsten content (metric tons)	Value (thousands)	Quantity, tungsten content (metric tons)	Value (thousands)
China	--	--	291	$3,220
France	(2)	$3	--	--
Germany	124	719	461	5,390
India	--	--	4	33
Mexico	--	--	4	35
Spain	--	--	15	132
Total	125	722	774	8,810

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 8

U.S. EXPORTS OF TUNGSTEN METAL POWDERS, BY COUNTRY[1, 2]

	2004			2005		
	Quantity			Quantity		
Country of destination	Gross weight (metric tons)	Tungsten content[3] (metric tons)	Value (thousands)	Gross weight (metric tons)	Tungsten content[3] (metric tons)	Value (thousands)
Australia	23	19	$643	10	8	$330
Austria	--	--	--	5	4	103
Brazil	11	9	647	13	11	618
Canada	65	52	1,880	92	74	3,280
Chile	1	1	37	2	2	105
China	19	15	804	32	26	1,430
Czech Republic	4	3	47	50	40	766
France	16	13	871	22	18	1,340
Germany	169	135	4,670	319	255	8,810
Hong Kong	3	2	308	1	1	20
India	2	2	53	4	3	199
Israel	20	16	218	41	33	590
Italy	31	25	1,770	39	31	1,970
Japan	17	13	832	28	22	1,180
Korea, Republic of	12	9	328	2	2	159
Martinique	--	--	--	4	4	115
Mexico	6	5	111	19	15	216
Netherlands	1	1	53	3	3	98
Norway	4	3	104	(4)	(4)	6
Serbia and Montenegro	--	--	--	5	4	85
Singapore	6	5	333	20	16	908
South Africa	1	1	61	2	2	112
Spain	3	3	163	11	9	245
Sweden	13	10	251	(4)	(4)	18
Switzerland	13	10	658	8	6	264
Taiwan	45	36	1,460	54	43	1,830
Thailand	2	2	87	2	2	103
Turkey	2	2	115	4	3	247
United Kingdom	40	32	1,840	77	62	2,130
Venezuela	8	7	181	61	49	1,030
Other	4 r	3 r	150 r	4	3	229
Total	542	433	18,700	937	750	28,500

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]May include tungsten alloy powders.

[3]Content estimated from reported gross weight.

[4]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 9

U.S. EXPORTS OF TUNGSTEN CARBIDE POWDER, BY COUNTRY[1]

	2004		2005	
Country of destination	Quantity, tungsten content (metric tons)	Value (thousands)	Quantity, tungsten content (metric tons)	Value (thousands)
Australia	12	$274	19	$596
Austria	7	203	1	13
Belgium	12	243	3	173
Brazil	4	108	5	137
Canada	102	2,550	101	3,620
China	10	173	2	183
France	152	2,320	134	3,180
Germany	224	3,120	308	5,090
Iceland	--	--	7	236
India	19	309	20	586
Ireland	9	457	12	721
Israel	(2)	9	7	126
Italy	6	138	3	171
Japan	20	574	14	484
Korea, Republic of	23	578	6	360
Luxembourg	35	552	2	63
Malaysia	(2)	7	3	97
Mexico	4	91	3	219
Norway	2	90	4	307
Russia	--	--	3	38
Singapore	4	221	4	266
South Africa	30	472	120	3,330
Spain	5	61	6	211
Sweden	167	2,040	252	4,520
Switzerland	3	106	7	248
Taiwan	7	285	17	412
United Kingdom	568	8,790 r	480	11,800
Venezuela	--	--	3	50
Other	10 r	372 r	10	597
Total	1,440	24,200	1,560	37,800

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 10

U.S. EXPORTS OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY[1]

Product and country of destination	2004 Quantity, tungsten content (metric tons)	2004 Value (thousands)	2005 Quantity, tungsten content (metric tons)	2005 Value (thousands)
Ferrotungsten and ferrosilicon tungsten:				
Canada	1	$17	4	$108
Chile	(2)	6	--	--
Mexico	98	238	25	88
Total	99	261	29	196
Unwrought tungsten:[3, 4, 5]				
Australia	1	4	19	79
Brazil	20	101	8	49
Canada	14	280	54	517
Chile	--	--	3	12
China	6	27	7	28
Denmark	--	--	10	48
France	23	98	(2)	3
Germany	78	332	130	546
Hungary	69	328	16	84
Ireland	--	--	2	9
Israel	2	10	2	8
Italy	34	143	4	17
Japan	7	30	51	215
Korea, Republic of	1	3	28	136
Malaysia	15	68	30	141
Mexico	127	637	28	146
Netherlands	19	164	12	52
Peru	--	--	3	13
Philippines	--	--	8	32
Singapore	3	13	13	54
Sweden	5	43	25	103
Switzerland	11	99	1	35
Taiwan	262	1,170	340	1,630
Turkey	16	67	--	--
United Kingdom	37	189	129	656
Yemen	--	--	41	174
Other	1 r	3 r	3	15
Total	754	3,810	966	4,800
Waste and scrap:[4]				
Armenia	7	40	13	48
Australia	--	--	(2)	4
Austria	--	--	148	916
Belgium	74	452	20	351
Brazil	3	24	7	100
Canada	22	174	56	411
China	60	463	5	26
Germany	119	911	145	1,780
India	110	616	3	9
Japan	13	136	277	4,380
Korea, Republic of	--	--	3	16
Mexico	2	11	6	37
Netherlands	43	223	45	260
Singapore	2	11	4	21
Sweden	11	132	2	10

See footnotes at end of table.

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TABLE 10—Continued

U.S. EXPORTS OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY[1]

Product and country of destination	2004 Quantity, tungsten content (metric tons)	2004 Value (thousands)	2005 Quantity, tungsten content (metric tons)	2005 Value (thousands)
Waste and scrap—Continued:[4]				
Taiwan	7	$39	(2)	$4
United Arab Emirates	3	48	--	--
United Kingdom	50	390	124	1,050
Total	525	3,670	858	9,420
Wrought tungsten:[3, 4, 6]				
Brazil	3	675	11	1,370
Canada	44	2,590	35	2,440
China	5	1,050	4	1,090
Colombia	6	2,090	7	2,470
Czech Republic	10	977	18	2,780
France	6	1,210	4	1,070
Germany	36	3,390	82	5,400
Hong Kong	2	319	(2)	45
Hungary	8	1,130	6	1,380
India	13	642	8	444
Israel	3	276	4	797
Italy	4	390	3	674
Japan	97	7,720	119	13,200
Korea, Republic of	5	1,460	2	829
Mexico	36	5,590	33	4,180
Netherlands	(2)	100	2	571
Philippines	3	157	4	275
Singapore	2	260	2	355
Slovakia	2	362	1	217
Spain	19	895	18	808
Sweden	2	238	2	278
Taiwan	2	585	3	595
United Arab Emirates	2	188	1	98
United Kingdom	17	1,530	26	1,930
Other	8	2,050 r	10	2,600
Total	334	35,900	404	46,500
Tungsten compounds:[7]				
Canada	7	17	454	1,330
China	--	--	39	264
France	1	23	(2)	12
Mexico	12	74	--	--
Netherlands	--	--	20	456
United Kingdom	--	--	38	410
Other	(2)	8	1	54
Total	20	122	553	2,530

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

[3]May include alloys.

[4]Content estimated from reported gross weight.

[5]Includes bars and rods produced simply by sintering; excludes powders and waste and scrap.

[6]Includes bars and rods other than those produced simply by sintering; profiles, plates, sheets, strip, and foil; wire; and other wrought products.

[7]Includes only other tungstates.

Source: U.S. Census Bureau.

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TABLE 11
U.S. IMPORTS FOR CONSUMPTION OF TUNGSTEN ORES AND CONCENTRATES, BY COUNTRY[1]

Country of origin	2004 Quantity, tungsten content (metric tons)	2004 Value (thousands)	2005 Quantity, tungsten content (metric tons)	2005 Value (thousands)
Bolivia	504	$3,620	547	$10,200
Canada	778	3,710	270	1,300
China	(2)	21	1	2
Congo (Kinshasa)	28	97	57	500
Hong Kong	--	--	(2)	5
Kenya	38	177	--	--
Mexico	3	10	30	221
Mongolia	30	85	13	76
Portugal	514	4,710	764	16,200
Russia	--	--	97	593
Rwanda	138	657	140	871
Thailand	228	1,230	146	1,430
Uganda	8	50	--	--
United Kingdom	23	180	--	--
Vietnam	19	71	19	74
Total	2,310	14,600	2,080	31,400

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF AMMONIUM PARATUNGSTATE, BY COUNTRY[1]

Country of origin	2004 Quantity, tungsten content (metric tons)	2004 Value (thousands)	2005 Quantity, tungsten content (metric tons)	2005 Value (thousands)
China	1,830	$14,000	1,790	$28,600
Germany	198	2,010	69	811
Hong Kong	48	368	60	494
Japan	15	156	--	--
Total	2,090	16,500	1,920	29,900

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF FERROTUNGSTEN AND FERROSILICON TUNGSTEN, BY COUNTRY[1]

Country of origin	2004 Quantity, tungsten content (metric tons)	2004 Value (thousands)	2005 Quantity, tungsten content (metric tons)	2005 Value (thousands)
Brazil	43	$412	42	$474
China	349	3,100	342	4,920
Total	392	3,510	385	5,390

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 14

U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY[1]

Product and country of origin	2004 Quantity, tungsten content (metric tons)	2004 Value (thousands)	2005 Quantity, tungsten content (metric tons)	2005 Value (thousands)
Tungsten metal powders:[2]				
Austria	18	$314	8	$161
Belgium	4	96	10	206
Canada	97	1,520	100	3,140
China	714	8,370	614	12,600
Germany	392	6,590	405	12,400
Iceland	--	--	8	16
Israel	81	1,450	237	7,370
Japan	25	1,620	16	1,280
Korea, Republic of	131	2,320	135	4,310
Mexico	25	156	--	--
Other	(3) r	7 r	1	90
Total	1,490	22,400	1,530	41,500
Tungsten carbide powder:				
Canada	520	8,680	486	14,700
China	759	9,660	829	19,000
Czech Republic	6	176	9	636
France	8	695	7	454
Germany	51	976	20	846
Hong Kong	28	341	40	376
India	(3)	3	7	63
Israel	322	4,840	282	6,730
Italy	33	27	--	--
Japan	1	98	1	144
Korea, Republic of	24	377	6	168
Other	1	80 r	(3)	55
Total	1,750	26,000	1,690	43,200
Unwrought tungsten:[2, 4, 5]				
Austria	2	32	--	--
China	150	1,320	182	2,820
Germany	2	89	(3)	14
Russia	--	--	34	537
Singapore	12	193	26	276
Other	2	158	1	131
Total	166	1,790	243	3,780
Waste and scrap:				
Belgium	17	394	6	102
Canada	63	357	265	1,330
China	126	1,260	174	2,670
France	2	14	54	679
Germany	489	3,440	682	8,580
Hong Kong	121	946	62	948
India	16	111	82	762
Israel	17	154	8	47
Japan	160	1,070	235	3,250
Korea, Republic of	23	52	45	336
Mexico	8	88	57	488
Netherlands	--	--	109	1,000
Russia	19	112	--	--

See footnotes at end of table.

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TABLE 14—Continued

U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY[1]

Product and country of origin	2004		2005	
	Quantity, tungsten content (metric tons)	Value (thousands)	Quantity, tungsten content (metric tons)	Value (thousands)
Waste and scrap—Continued:				
South Africa	18	$121	48	$482
Sweden	11	89	39	261
Switzerland	16	111	16	369
United Arab Emirates	--	--	142	2,180
United Kingdom	43	394	23	418
Other	5 r	21 r	18	178
Total	1,150	8,730	2,070	24,100
Wrought tungsten:[2, 4, 6]				
Austria	28	3,220	25	4,070
Belgium	2	268	11	581
China	117	5,380	123	7,200
Czech Republic	5	1,150	1	337
France	(3)	116	9	997
Germany	25	2,770	20	2,730
Hong Kong	7	508	7	633
Hungary	6	527	5	643
India	4	456	7	465
Israel	3	300	28	1,590
Japan	47	5,160	41	5,220
Mexico	3	22	(3)	32
Russia	4	283	9	869
South Africa	--	--	8	118
Taiwan	11	148	(3)	64
United Kingdom	4	652	5	296
Other	4 r	776 r	6	1,540
Total	270	21,700	306	27,400
Tungsten oxides:				
China	558	6,880	680	17,300
Germany	7	136	3	119
Hong Kong	14	151	(3)	15
Liechtenstein	41	701	--	--
Netherlands	50	360	--	--
Russia	193	1,740	233	5,500
United Kingdom	41	749	(3)	3
Other	--	--	1	18
Total	905	10,700	917	23,000
Other tungstates:				
Australia	(3)	4	(3)	11
China	(3)	4	--	--
Germany	5	89	(3)	33
India	(3)	11	(3)	12
Japan	(3)	9	(3)	7
United Kingdom	(3)	26	2	50
Total	6	142	3	113
Other tungsten compounds:[7]				
Germany	1	226	(3)	114
Japan	4	656	4	681
Ukraine	--	--	(3)	7
United Kingdom	(3)	3	--	--
Total	4	885	4	802

See footnotes at end of table.

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TABLE 14—Continued

U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS TUNGSTEN-BEARING MATERIALS, BY COUNTRY[1]

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]May include alloys.

[3]Less than ½ unit.

[4]Content estimated from reported gross weight.

[5]Includes bars and rods produced simply by sintering; excludes powders and waste and scrap.

[6]Includes bars and rods other than those produced simply by sintering; profiles, plates, sheets, strip, and foil; wire; and other wrought products.

[7]Includes tungsten chlorides.

Source: U.S. Census Bureau.

TABLE 15

TUNGSTEN: WORLD CONCENTRATE PRODUCTION, BY COUNTRY[1, 2]

(Metric tons, tungsten content)

Country[3]	2001	2002	2003	2004	2005[e]
Australia	15	7	2	2	2
Austria	1,429 [r]	1,377 [r]	1,381 [r]	1,335 [r]	1,350
Bolivia	532	399	441	401 [r]	522 [4]
Brazil	22	24	30 [r]	262 [r]	250
Burma[5]	85 [r]	83	93	106 [r]	100
Burundi	--	--	13 [r]	9 [r]	10
Canada[6]	--	2,295	3,636	--	700 [4]
China[e]	42,100	55,100	55,500	60,000 [r]	61,000
Korea, North[e]	500	600	600	600	600
Mongolia	63	35	40 [e]	77 [r]	78 [4]
Portugal	698	693	715	746	815 [4]
Russia[e]	5,100 [r]	5,300 [r]	5,450 [r]	5,500 [r]	4,400
Rwanda	142	153	78	120 [e]	120
Thailand[e]	50	31	208	180 [r]	150
Uganda	17	16	1	52 [r]	--
Total	50,800 [r]	66,100 [r]	68,200 [r]	69,400 [r]	70,100

[e]Estimated. [r]Revised. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through May 25, 2006.

[3]Tungsten concentrates are believed to be produced in Nigeria, Peru, and Turkey and may be produced from tin-tungsten ores in Kyrgyzstan, but information is inadequate to make reliable estimates of production.

[4]Reported figure.

[5]Includes tungsten content of tin-tungsten concentrate produced by state-owned mining enterprises under the Ministry of Mines.

[6]Tungsten content of concentrates shipped.

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VANADIUM

By Michael J. Magyar

Domestic survey data and tables were prepared by Subina W. Pandey, statistical assistant, and the world production tables were prepared by Regina R. Coleman, international data coordinator.

In 2005, reported vanadium consumption in the United States was 3,910 metric tons (t) of contained vanadium, a 3% decrease from that of 2004. The United States imported 11,900 t of ferrovanadium (FeV), measured in vanadium content, 1,370 t of vanadium pentoxide (V_2O_5), and 186 t of other oxides and hydroxides of vanadium, collectively valued at $190 million. Total imports for consumption of these vanadium materials increased by 222% from those of 2004, driven largely by FeV imports. The United States exported 504 t of FeV, 254 t of V_2O_5, and 899 t of other oxides and hydroxides of vanadium valued at $40.2 million. Total exports of these vanadium-bearing materials increased by 49% from those of 2004.

Vanadium was produced in the United States solely by recovery of vanadium from various industrial waste materials, such as vanadium-bearing fly ash, petroleum residues, pig iron slag, and spent catalysts. Fewer than 10 firms, primarily in Arkansas, Louisiana, and Texas, processed these materials to produce V_2O_5, FeV, and vanadium metal. Metallurgical applications in which vanadium was used as an alloying element with iron, steel, and titanium remained the dominant end use. Catalysts represent the leading nonmetallurgical use for vanadium.

Legislation and Government Programs

Ferrovanadium antidumping duties levied against China, Russia, and South Africa, the three leading vanadium producers in the world, continued to be enforced. On July 10, 1995, the U.S. Department of Commerce (DOC) issued an antidumping order on FeV and nitrided vanadium imports from Russia. Following the latest 5-year review, the DOC issued a continuation of the antidumping duty order on these Russian imports, which had been made effective June 7, 2001. The next 5-year review of the antidumping duty order on Russian FeV and nitrided vanadium will be effective May 1, 2006 (U.S. International Trade Commission 2006§[1]).

Production

The major vanadium commodities are aluminum-vanadium master alloys, FeV, vanadium-bearing ash, residues and slag, vanadium chemicals, and V_2O_5 and other oxides and hydroxides of vanadium. In 2005, companies in the United States produced all of these materials with the exception of vanadium-bearing slag from the manufacture of iron and steel. Vanadium-containing steels can be subdivided into microalloy or low-alloy steels, that generally contain less than 0.15% vanadium, and high-alloy steels that contain as much as 5% vanadium.

With the closure of the CS Metals of Louisiana LLC. catalyst recycling facility in Covenant, LA, in December 2004, Strategic Minerals Corp. (Stratcor) made other arrangements for vanadium to replace the 10% of their feedstock that CS Metals had provided. CS Metals had the capacity to recover about 1,800 metric tons per year (t/yr) (4 million pounds per year) of V_2O_5 from spent catalysts, but market sources doubted the company had been operating at above 50% of capacity. Stratcor reopened its Vametco Mine in Britts, South Africa, to supplement other feed sources for its South African ferrovanadium plant. Stratcor's contract for purchase of vanadium-bearing slag from Highveld Steel and Vanadium Corp. Ltd. runs through 2006, and Stratcor had other slag sources as well (Ryan's Notes, 2005a).

Stratcor, Danbury, CT, announced plans to consolidate its vanadium chemicals production operations at a new vanadium-halide facility under construction at its Hot Springs, AR, facility. The new facility, expected to be ready by early 2006, would replace an existing facility at Niagara Falls, NY. The consolidation was expected to streamline chemical operations because the Hot Springs facility already supplied the V_2O_5 feedstock for the Niagara Falls facility. The vanadium halides (vanadium oxytrichloride, vanadium tetrachloride, and vanadium-titanium mixes) are used to make catalysts for the production of polyethylene, synthetic rubber, and other chemicals (Ryan's Notes, 2005b).

Eramet International Group, Paris, France, announced that its subsidiary Gulf Chemical & Metallurgical Corp. acquired 100% of Bear Metallurgical Co. (BMC), Butler, PA. BMC, the leading FeV and the second ranked ferromolybdenum (FeMo) producer in the United States, had operated as a toll converter. Gulf, a catalyst recycler, previously owned 49.5% of BMC (Ryan's Notes, 2005d).

Northwestern Mineral Ventures Inc., Toronto, Ontario, Canada, acquired 100% ownership of the Firefly uranium-vanadium project in Utah's La Sal uranium district. The Firefly project included the Firefly and Gray Duran Mines and 39 mining claims. The Firefly and Gray Duran Mines produced uranium for about 25 years starting in 1953 and coproduced vanadium ore that contained more than 2% V_2O_5. The company's objective was to return the Firefly Mine to production, pending completion of an engineering study and obtaining permits (Platts Metals Week, 2005b).

Consumption

The U.S. Geological Survey (USGS) derived vanadium consumption data from a voluntary survey of domestic consuming companies. For this survey, more than 80 companies were canvassed on a monthly and/or annual basis. Some

[1]References that include a section mark (§) are found in the Internet References Cited section.

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industry estimates indicate that actual domestic consumption is much greater than reported consumption.

Metallurgical applications continued to dominate U.S. vanadium use in 2005, accounting for 93% of reported consumption. Nonmetallurgical applications included catalysts, ceramics, electronics, and vanadium chemicals. The dominant nonmetallurgical use was in catalysts. Based on USGS data, reported domestic vanadium consumption in 2005 was 3,910 t, a decrease of 3% from that of 2004. This slight decline in reported vanadium consumption reflected stable demand by steel producers, with reduced FeV imports from China, Russia, and South Africa, owing to antidumping duties, being offset by imports of FeV from the Czech Republic.

Most vanadium is consumed in the form of FeV, which is used as a means of introducing vanadium into steel, in which it provides additional strength and toughness. FeV is available as alloys containing 45% to 50% or 80% vanadium. The 45%- to 50%-grade FeV is produced by the silicothermic reduction of V_2O_5 in slag or other vanadium-containing materials. Most of the 80%-grade FeV is produced by the aluminothermic reduction of V_2O_5 in the presence of steel scrap or by direct reduction in an electric arc furnace.

Prices

In 2005, the price for domestic FeV, as published in Metal Bulletin, ranged from $22.00 to $61.00 per pound of contained vanadium, compared with $6.20 to $23.00 per pound reported in 2004. The price rose from about $22.00 per pound at the beginning of the year in January, gradually increased to about $43.00 per pound by the end of April, spiked to about $61.00 per pound in May, and then gradually dropped down to $22.00 per pound in December. The European FeV price ranged from $34.00 to $128.00 per kilogram compared with $14.70 to $52.00 per kilogram in 2004. The European price rose gradually from about $48.00 per kilogram at the beginning of the year in January, spiked to about $128.00 per kilogram in April, dropped to about $34.00 per kilogram in August, and rebounded to about $63.00 per kilogram through October before drifting down to $43.00 per kilogram in December.

The Metal Bulletin published price for domestic V_2O_5 ranged between $7.50 and $27.00 per pound in 2005, compared with $2.75 and $9.80 per pound in 2004. The price rose gradually from $9.50 per pound in January to spike at $27.00 per pound in June, then dropped to $7.50 per pound in August, and rose to about $14.00 per pound by November before drifting down to about $10.00 per pound in December.

World Industry Structure

Nearly all of the world's supply of vanadium is from primary sources. Five countries recovered vanadium from ores, concentrates, slag, or petroleum residues (table 7). In four of the five countries, the mining and processing of magnetite-bearing ores was an important source of vanadium production. The leading vanadium-producing nations remained China and South Africa. Japan and the United States were believed to be the only countries to recover significant quantities of vanadium from petroleum residues.

Recycling of vanadium-containing alloys for recovery of vanadium was negligible and involved mainly a small quantity of tool steel. Vanadium's major end use was as an alloying-element in iron, steel, and titanium-bearing alloys, from which it is lost to slag and not recovered when those metals are recycled. Only small quantities of vanadium were recovered from recycling vanadium-bearing catalysts and that material was reused to make new catalysts.

World Review

Australia.—Precious Metals Australia Ltd. (PMA) won a small victory in its effort to seek damages against Xstrata, Plc. for mothballing the Windimurra Mine in Western Australia in December 2002. Xstrata Alloys (a subsidiary of Xstrata, Plc.) agreed to pay PMA A$10 million to cover royalty payments and final rehabilitation of the Windimurra site and A$5 million in full and final settlement of all outstanding claims by PMA related to Windimurra. In a separate transaction, Xstrata sold the tenements, remaining Windimurra project assets, and all project information to PMA. The transaction was conditional on the Western Australian government approving the transfers and necessary releases within the next 6 months. Industry sources doubted that PMA could reopen Windimurra any time soon (Ryan's Notes, 2005h).

PMA selected The Hatch Group to study the feasibility of reopening the closed Windimurra Mine in Western Australia. The first stage, which was completed in December, identified process and plant design options and estimated capital and operating costs. The second phase, to be completed by May 2006, would finalize the engineering design and update cost estimates. Hatch would also analyze market risks and strategy and prepare a new ore reserve estimate. PMA had previously announced that the reopened Windimurra project would exceed Windimurra's previous capacity of 7,700 t/yr (17 million pounds per year) of V_2O_5 (Platts Metals Week, 2005d).

PMA, West Perth, Australia, raised A$13.3 million (US$10.2 million) to reopen the Windimurra Mine in Western Australia. The funds were raised by placement of 19 million additional shares in the company by international investors. PMA also sought a listing on the London Stock Exchange's Alternative Investment Market. The new funds were for assessment of the feasibility of redeveloping Windimurra, for purchasing plant equipment for redevelopment, and for working capital. PMA planned to add a FeV conversion facility at Windimurra and increase the project's capacity to the equivalent of 10,000 t/yr (20 million to 22 million pounds per year) of V_2O_5 (Platts Metals Week, 2005c).

Aurox Resources Limited hoped to become a low-cost vanadium producer by developing the Balla Balla vanadium-titanium-iron ore deposit in northwestern Western Australia. Aurox agreed to pay A$200,000 (US$156,000) for an option on Balla Balla. Identified resources at the site were 75 million metric tons of ore grading 0.8% V_2O_5 with the potential to produce 4,000 t/yr of FeV. Under the terms of the agreement, Aurox secured an exclusive 6- to 9-month review period prior

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to deciding whether to proceed with a bankable feasibility study (Platts Metals Week, 2005a).

Canada.—Metallurg Vanadium Corp. announced plans to build a spent-catalyst calcining facility in Alberta, to process spent catalysts from the Alberta tar sands projects. In addition, Metallurg planned to expand its FeV and ferronickel-molybdenum production capability at its Cambridge, OH, processing facility. The Alberta facility would provide additional feed material to the expanded Cambridge operation, although Metallurg did not specify how much additional capacity would be added. Both projects were expected to be completed by the end of 2007 (Ryan's Notes, 2005f).

Gulf also announced plans to build a new catalyst recycling facility in Edmonton, Alberta to process spent catalysts from Canadian oil sands refining. Residues recovered at the new facility would be converted to FeV and FeMo at BMC in Butler, PA, allowing Gulf to quickly double its FeV and FeMo production after the new facility comes online (Ryan's Notes, 2005d).

China.—Chinese vanadium producer Chengde Xinxin Vanadium & Titanium Co., Ltd. produced more than 2,100 t of V_2O_5 in the first half of 2005 from vanadium-bearing slag residues, up by 8% from that of the first half of 2004. The company expected to produce about 6,000 t during the full year owing to increased steel production by its parent company, Chengde Iron & Steel Group Co., Ltd. About two-thirds of the V_2O_5 was used internally in the production of FeV, and the remainder was exported (Ryan's Notes, 2005b).

Six new V_2O_5 smelters were being constructed in the Dunhuang area of northwestern Gansu Province, China, with a reported total capacity of 3,000 t/yr. The smelters were to be supported by the Fangshankou Mine, China's fourth largest vanadium deposit (Metal Pages, 2005b§).

Czech Republic.—Negotiations for the purchase of V_2O_5- to FeV-converter Nikom A.S. started with Russian producer JSC Vanadii-Tulachermet (Tula) and Glencore International AG (which markets production from Xstrata) engaged in talks with Nikom's owners. The majority of Nikom's 3,500-t/yr FeV production capacity was being used by Tula, because Tula did not have sufficient conversion capacity in Russia. Antidumping duties placed on vanadium material imported into the United States from Russia increased the plant's strategic significance to the vanadium market (Metal Bulletin, 2005a).

Japan.—In a joint venture with Mitsubishi Corporation and Kashina Kyodo Power, JFE Material Co., Ltd., announced plans to begin production of 2,000 t/yr of FeV and 2,000 t/yr of FeMo and ferronickel in January 2006. Mitsubishi and Kashina will supply vanadium-bearing spent desulfurization catalysts and boiler residues to the joint venture, Metal Technology Inc., and the FeV and FeMo products will be sold to JFE Steel Corporation and other affiliated specialty steel plants. JFE Material estimated that 140,000 t/yr of these vanadium-bearing wastes was available in Japan and expected to process about 40,000 t/yr in the new plant (Ryan's Notes, 2005e).

Russia.—When it purchased 50% of Nikom for $1.5 million, Tula not only strengthened its position in the vanadium market, it also changed the dynamics of the Russian vanadium industry. The deal gave Tula exclusive rights to convert V_2O_5 to FeV at Nikom's plant, effectively eliminating the possibility of traders converting material for sale on the free market. Tula also announced plans to invest in Nikom to create a reliable warehouse facility in Europe to improve the logistics of supply (Metal Bulletin, 2005b).

Tula is believed to have FeV capacity of 10,700 t/yr. Russian exports of FeV totaled 8,670 t in 2004, up by 50% from those of 2003. Russian exports of V_2O_5 in 2004 totaled 3,000 t, about the same as in 2003 (Ryan's Notes, 2005c).

South Africa.—Vanadium producers agreed that plant and mine closures, along with a surge in demand, helped boost prices in 2004. With prices elevated, some producers explored ways to increase output. Highveld Steel and Vanadium Corp. Ltd. reported that all three of its kilns at its Vanchem facility near Witbank operated during 2004, with stoppages only for annual maintenance. The company started a capital improvement program aimed at upgrading plant and equipment in the kiln and oxide areas to improve efficiencies and debottleneck. Highveld announced plans to increase vanadium production capacity by 30% by the end of 2006 from 10,000 t/yr of contained vanadium (Metal Pages, 2005c§).

Xstrata told analysts that its fully integrated Rhovan vanadium operation was well positioned to capitalize on future expansion options. Sources believe that Xstrata increased production at Rhovan to compensate for lost production when it permanently closed its Vantech V_2O_5 plant in South Africa in 2004. Rhovan's production capacity is about 10,000 t/yr of V_2O_5 and 7,800 t/yr of FeV (Ryan's Notes, 2005g).

Current Research and Technology

McKenzie Bay International Ltd., owner of North America's largest vanadium deposit, hired Brooks, Houghton & Co. Inc. to look at options for its Lac Dore Mining Inc., subsidiary. Potential options included sale of the company, the 443 contiguous mining claims for the Lac Dore deposit, and proprietary refining technology developed during the feasibility study (Metal Pages, 2005a§). McKenzie Bay decided to focus on its WindStor renewable-energy generation, storage, and distribution system and would use any funds generated by the sale for the pending commercialization of WindStor. The WindStor system combines Dermond Inc.'s vertical axis wind turbine, called the WindStor Wind Turbine (WWT), with a vanadium-base battery storage system and a proprietary system integrator to provide stored electricity to users (McKenzie Bay International Ltd., 2004§).

Outlook

Vanadium's primary use was as a hardening agent in steel. Raw steel production in China rose by 25% to 350 million metric tons (Mt) in 2005, pushing global raw steel production to 1.13 billion metric tons, a 6% increase compared with the 2004 record-high production (Advanced Steel News, 2006§). The surge in global steel production increased demand for vanadium and drove prices for domestic V_2O_5 to a record $27.00 per pound in May. World production of vanadium rose by more than 13% to 59,000 t of contained vanadium (230 million

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pounds of V_2O_5) in 2005. With steel production expected to be strong for the next 3 to 5 years, strong demand for vanadium should be sustained.

The capacity to recover vanadium from catalysts, petroleum residues, and slag worldwide was estimated to be 81,700 t/yr (180 million pounds per year) of V_2O_5, and primary mines add another 24,500 t/yr (54 million pounds per year) of V_2O_5 capacity (Ryan's Notes, 2004). As a result of production capacity increases from expansions, increased world demand is expected to be satisfied from existing resources for the foreseeable future.

Because of abundant resources and adequate production capacity in China, Russia, and South Africa, world producers are expected to readily meet future vanadium requirements. Increased recovery of vanadium from fly ash, petroleum residues, slag, and spent catalyst is also expected.

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TABLE 1
SALIENT VANADIUM STATISTICS[1]

(Metric tons of contained vanadium, unless otherwise specified)

	2001	2002	2003	2004	2005
United States:					
Production, ore and concentrate:					
Recoverable vanadium:[2]					
Value thousand dollars	--	--	--	--	--
Vanadium oxide recovered from ore[3]	--	--	--	--	--
Consumption	3,210	3,080	3,240	4,050	3,910
Exports:					
Ferrovanadium	70	142	397 r	285	504
Vanadium pentoxide (anhydride)	71 r	91 r	185 r	240 r	254
Other oxides and hydroxides of vanadium	63 r	203 r	284 r	584 r	899
Imports for consumption:					
Ferrovanadium	2,550	2,520	1,360 r	3,020 r	11,900
Ore, slag, ash, residues	1,670	1,870	3,060 r	2,350 r	1,690
Vanadium pentoxide (anhydride)	600	406	474 r	1,040 r	1,370
Other oxides and hydroxides of vanadium	57	66	74	120 r	186
Stocks:					
Ferrovanadium	239	212 r	213 r	320 r	343
Oxide	6 r	7 r	6	6	2
Other[4]	13 r	14 r	33 r	10 r	26
World, production from ore, concentrate, slag	41,800 r	51,000 r	47,900 r	51,900 r	58,800 e

eEstimated. rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits. Quantities are contained vanadium.

[2]Recoverable vanadium contained in uranium and vanadium ores and concentrates received at mill, plus vanadium recovered from ferrophosphorous slag derived from domestic phosphate rock.

[3]Produced directly from all domestic ores and ferrophosphorous slag; includes metavanadates.

[4]Consists principally of vanadium-aluminum alloy, small quantities of other vanadium alloys, vanadium metal, and ammonium metavanadate.

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TABLE 2

U.S. CONSUMPTION OF VANADIUM, BY END USE AND FORM[1]

(Kilograms of contained vanadium)

	2004	2005
End use:		
Steel:		
Carbon	1,300,000	1,170,000
Full alloy	1,060,000	1,010,000
High-strength low-alloy	1,160,000	974,000
Stainless and heat resisting	60,000	60,000
Tool	239,000	402,000
Total	3,820,000	3,620,000
Cast irons	W	W
Superalloys	16,600	35,600
Alloys (excluding steels and superalloys):		
Welding and alloy hard-facing rods and materials	W	W
Other alloys[2]	W	W
Chemical and ceramic uses:		
Catalysts	W	W
Pigments	W	W
Miscellaneous and unspecified	215,000 r	259,000
Grand total	4,050,000 r	3,910,000
Form:		
Ferrovanadium	3,610,000 r	3,290,000
Oxide	269,000	344,000
Other[3]	180,000	274,000
Total	4,050,000 r	3,910,000

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes magnetic alloys.

[3]Consists principally of vanadium-aluminum alloy, small quantities of other vanadium alloys, vanadium metal, and ammonium metavanadate.

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TABLE 3
U.S. IMPORTS AND EXPORTS OF ALUMINUM-VANADIUM MASTER ALLOY AND VANADIUM METAL, INCLUDING WASTE AND SCRAP[1]

	Aluminum-vanadium master alloy		Vanadium metal, including waste and scrap	
	Quantity, gross weight (kilograms)	Value	Quantity, gross weight (kilograms)	Value
Imports for consumption:				
2004	19,100	$66,700	31,200	$1,710,000
2005:				
China	1,000	2,370	--	--
Germany	--	--	44,500	2,490,000
Mexico	--	--	379	3,120
Russia	--	--	9,920	1,310,000
United Kingdom	10	13,100	1	2,310
Total	1,010	15,500	54,800	3,800,000
Exports:				
2004	14,600,000 r	32,200,000 r	522,000	7,760,000
2005:				
Australia	105,000	436,000	901	51,800
Austria	--	--	8,950	389,000
Barbados	270	3,500	--	--
Belgium	49,400	802,000	5,000	185,000
Brazil	55,800	289,000	--	--
Canada	1,930,000	6,590,000	1,850	51,900
China	27,900	303,000	--	--
Denmark	702	9,130	--	--
France	23,800	80,900	5,320	381,000
Germany	4,780	96,200	2,950	498,000
Guatemala	1,080	11,800	--	--
Hong Kong	683	8,890	--	--
India	125,000	354,000	--	--
Ireland	1,740	22,700	--	--
Israel	--	--	35	41,800
Italy	1,510	7,850	--	--
Japan	514,000	7,540,000	108,000	5,330,000
Korea, Republic of	18,800	119,000	150	9,950
Malaysia	14,900	117,000	--	--
Mexico	11,500,000	25,300,000	2,980	188,000
Spain	4,700	52,000	--	--
Switzerland	906	11,300	3	13,600
Taiwan	124,000	581,000	--	--
Thailand	389,000	1,830,000	--	--
United Kingdom	165,000	1,030,000	156,000	9,250,000
Total	15,100,000	45,600,000	293,000	16,400,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 4

U.S. IMPORTS AND EXPORTS OF FERROVANADIUM, VANADIUM PENTOXIDE (ANHYDRIDE), AND OTHER OXIDES AND HYDROXIDES OF VANADIUM[1]

	Ferrovanadium		Vanadium pentoxide (anhydride)[2]		Other oxides and hydroxides of vanadium	
	Quantity, V content (kilograms)	Value	Quantity, V content (kilograms)	Value	Quantity, V content (kilograms)	Value
Imports for consumption:						
2004	3,020,000 r	$62,100,000	1,040,000 r	$8,600,000	120,000 r	$1,650,000
2005:						
Australia	19,000	916,000	40,300	1,450,000	--	--
Austria	86,500	6,560,000	16,600	856,000	67,500	4,700,000
Canada	194,000	12,000,000	--	--	--	--
China	100,000	168,000	209,000	9,040,000	--	--
Czech Republic	11,000,000	88,900,000	--	--	--	--
Germany	974	73,100	166	12,400	5,340	178,000
Japan	32,700	735,000	182	39,200	--	--
Korea, Republic of	74,000	5,130,000	--	--	--	--
Russia	--	--	25,100	647,000	--	--
South Africa	--	--	1,050,000	40,000,000	113,000	1,660,000
Swaziland	356,000	16,500,000	--	--	--	--
Sweden	400	16,900	--	--	--	--
Taiwan	--	--	27,300	858,000	--	--
United Kingdom	1,200	135,000	--	--	--	--
Total	11,900,000	131,000,000	1,370,000	52,900,000	186,000	6,540,000
Exports:						
2004	285,000	9,210,000	240,000 r	4,350,000 r	584,000 r	6,230,000
2005:						
Australia	170	8,450	--	--	--	--
Austria	17,200	989,000	4,060	157,000	24,400	217,000
Argentina	--	--	100	4,790	--	--
Belgium	--	--	22,400	606,000	--	--
Brazil	35,800	4,510,000	--	--	11,500	160,000
Canada	109,000	2,470,000	--	--	452,000	4,310,000
China	63,700	3,590,000	--	--	19,300	244,000
Denmark	--	--	327	11,300	--	--
France	--	--	11,200	102,000	--	--
Germany	--	--	12,500	424,000	15,000	1,080,000
Italy	--	--	109,000	2,190,000		
Japan	--	--	--	--	708	6,300
Latvia	--	--	18,000	580,000	--	--
Mexico	206,000	5,070,000	9,360	121,000	--	--
Netherlands	49,400	1,940,000	--	--	37,000	560,000
New Zealand			320	11,900		
Russia	--	--	7,680	218,000	306,000	8,540,000
South Africa	--	--	4,130	36,000	--	--
Spain	--	--	18,800	549,000	--	--
Trinidad and Tobago	--	--	28,400	307,000	11,400	88,000
United Kingdom	--	--	--	--	8,510	75,700
Venezuela	21,800	728,000	8,000	156,000	13,500	139,000
Total	504,000	19,300,000	254,000	5,470,000	899,000	15,400,000

rRevised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]May include catalysts that contain vanadium pentoxide.

Source: U.S. Census Bureau.

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TABLE 5

U.S. IMPORTS FOR CONSUMPTION OF VANADIUM-BEARING ASH, RESIDUES, AND SLAG[1]

Material and country	2004 Quantity, V_2O_5 content (kilograms)[r]	2004 Value	2005 Quantity, V_2O_5 content (kilograms)	2005 Value
Ash and residues:				
Canada	2,110,000	$1,920,000	1,200,000	$1,100,000
Guatemala	50,500	89,400	--	--
Mexico	946,000	8,430,000	1,060,000	9,820,000
South Africa	277	4,950	--	--
United Kingdom	16,300	80,800	--	--
Total	3,120,000	10,500,000	2,270,000	10,900,000
Slag, from the manufacture of iron and steel, South Africa[2]	1,080,000	1,290,000	756,000	1,510,000

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]As adjusted by the U.S. Geological Survey.

Source: U.S. Census Bureau.

TABLE 6

U.S. IMPORTS FOR CONSUMPTION OF MISCELLANEOUS VANADIUM CHEMICALS[1, 2]

Material and country	2004 Quantity, V content (kilograms)	2004 Value	2005 Quantity, V content (kilograms)	2005 Value
Sulfates:				
China	500	$19,100	--	--
South Africa	--	--	35,000	$77,000
Total	500	19,100	35,000	77,000
Vanadates:				
Canada	4,260 [r]	178,000	--	--
China	--	--	49	3,530
Germany	4,870 [r]	223,000	27,100	808,000
Japan	178 [r]	31,900	118	22,800
Korea, Republic of	--	--	11,800	76,800
Russia	--	--	4	2,640
South Africa	65,400 [r]	718,000	46,000	1,880,000
Switzerland	--	--	1	2,010
Total	74,700 [r]	1,150,000	85,100	2,800,000

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Comprises vanadium ore and miscellaneous vanadium chemicals.

Source: U.S. Census Bureau.

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TABLE 7

VANADIUM: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons of contained vanadium)

Country	2001	2002	2003	2004	2005
Production from ores, concentrates, slag:[3]					
Australia	2,660 [4]	3,060 [4]	160 [4]	150 [r, 4]	100
China[5]	12,000	13,200	13,200	16,000 [r]	17,000
Kazakhstan	1,000	1,000	1,000	1,000	1,000
Russia	7,500	8,000	5,800	10,900 [r]	15,100
South Africa	18,184 [4]	25,227 [r, 4]	27,172 [r, 4]	23,302 [r, 4]	25,000
Total	41,300	50,500 [r]	47,300 [r]	51,400 [r]	58,200
Production from petroleum residues, ash spent catalysts:[6]					
Japan	499 [r]	499 [r]	560 [r]	560 [r]	560
Grand total	41,800 [r]	51,000 [r]	47,900 [r]	51,900 [r]	58,800

[r]Revised.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]In addition to the countries listed, vanadium is also recovered from petroleum residues in Germany and several other European countries, but available information is insufficient to make reliable estimates. Table includes data available through June 7, 2006.

[3]Production in this section is credited to the country that was the origin of the vanadiferous raw material.

[4]Reported figure.

[5]Estimated 40% of vanadium recovered from vanadiferous slag.

[6]Production in this section is credited to the country where the vanadiferous product is extracted; available information is inadequate to permit crediting this output back to the country of origin of the vanadiferous raw material.

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VERMICULITE

By Michael J. Potter

Domestic survey data and tables were prepared by Nicholas A. Muniz, statistical assistant, and the world production table was prepared by Glenn J. Wallace, international data coordinator.

Production of vermiculite concentrate in the United States was an estimated 100,000 metric tons (t), about the same as in 2004. Worldwide vermiculite production increased to 527,000 t in 2005. U.S. exports were an estimated 5,000 t. U.S. imports were about 91,000 t, an increase of 31% from those of 2004. The average unit value of U.S. exfoliated vermiculite sold or used by producers increased by 5% compared with that of 2004.

Vermiculite is a hydrated magnesium-aluminum-iron silicate, with a generalized formula of $(Mg,Fe+^{2},Al)_3(Al,Si)_4O_{10}(OH)_2 \cdot 4H_2O$ (Fleischer and Mandarino, 1991, p. 211). Deposits of vermiculite are generally associated with ultramafic rocks rich in magnesium silicate minerals. Vermiculite is a secondary mineral formed primarily by the alteration of mica and less commonly by alteration of amphibole, chlorite, olivine, pyroxene, or other clay minerals. Flakes of raw vermiculite concentrate are mica-like in appearance and contain water molecules within their internal structure. When the flakes are heated rapidly at a temperature of 900° C or higher, the water flashes into steam, and the flakes expand into accordion-like particles. The color, which can range from black and various shades of brown to yellow for the raw flakes, changes upon expansion to gold or bronze. This expansion process is called exfoliation, and the resulting lightweight material is chemically inert, fire resistant, and odorless. In lightweight plaster and concrete, vermiculite provides good thermal insulation. Vermiculite can absorb liquids, such as fertilizers, herbicides, and insecticides, which can then be transported as free-flowing solids (Harben and Kuzvart, 1996).

Production

Domestic production (sold or used) data for vermiculite were collected by the U.S. Geological Survey (USGS) from two voluntary canvasses—one for mine-mill (concentrator) operations and the other for exfoliation plants. Production data for nonrespondents were estimated using employment data and/or adjusted production reports from prior years. The two U.S. producers of vermiculite concentrate were Virginia Vermiculite Ltd. with two operations (near Woodruff, SC, and in Louisa County, VA) and W.R. Grace & Co. from its operation at Enoree, SC.

Vermiculite concentrate was shipped to exfoliating plants for conversion into lightweight material. Output of exfoliated vermiculite sold or used in 2005, using actual and estimated data, was about 85,000 t, which was produced from both domestic and imported vermiculite concentrate (table 1). Exfoliated vermiculite was produced by 13 companies operating 17 plants in 10 States (table 2). Of the 17 exfoliation plants, 8 responded to the annual canvass, representing 61% of the estimated sold or used exfoliated vermiculite tonnages listed in tables 1 and 3. Data for the remaining operations were estimated from previous years' reported and estimated production levels. States that produced exfoliated vermiculite were, in descending order of estimated output sold or used, South Carolina, New Jersey, Pennsylvania, Arizona, Arkansas, Florida, Illinois, Massachusetts, Ohio, and New Mexico.

In November, Normiska Corp. of Canada acquired The Schundler Co. of Metuchen, NJ, a major expander of vermiculite and perlite supplying the eastern United States. Normiska is a horticultural company that also supplies composted pine bark, sphagnum peat moss, and mulches of varying specifications (Normiska Corp., undated§[1]).

Consumption

Vermiculite has a wide range of uses that take advantage of its various attributes of fire resistance, good insulation, high liquid absorption capacity, inertness, and low density (table 3). Vermiculite is used in general building plasters, either in its own formulations or combined with other lightweight aggregates such as perlite. Special plasters include fire protection and acoustic products in which vermiculite is combined with a binder, such as gypsum or portland cement, and fillers and rheological aids (Roskill Information Services Ltd., 2004, p. 103).

Exfoliated vermiculite, sometimes treated with a water repellent, is used to fill pores and cavities in masonry construction and hollow blockwork to enhance acoustic, fire rating, and insulation performance. Finer grades of exfoliated vermiculite, combined with potassium or sodium silicate, are used to produce insulation shapes. The ability of vermiculite-base insulation shapes to resist attack by molten aluminum makes them especially useful as secondary insulation in the aluminum production process (Roskill Information Services Ltd., 2004, p. 112).

In horticulture, exfoliated vermiculite improves soil aeration and moisture retention. When vermiculite is mixed with peat or other composted materials, such as pine bark, the resulting product provides a good growing medium for plant propagation (increasing the number of plants). As a soil conditioner, exfoliated vermiculite can improve the aeration of "sticky" soils (containing clay) and the water-holding characteristics of sandy soils. This allows for easier watering and reduces the likelihood of compaction, cracking, and crusting of the soil. Vermiculite is used in the fertilizer/pesticide market because of its ability to act as a carrier, bulking agent, and extender (Roskill Information Services Ltd., 2004, p. 108-109).

[1]References that include a section mark (§) are found in the Internet References Cited section.

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Other uses include refractory-insulation gunning and castable mixes and vermiculite dispersions. Finer grades of exfoliated vermiculite are used to partially replace asbestos in brake linings, primarily for the automotive market (Roskill Information Services Ltd., 2004, p. 112-113).

Prices

Published prices for vermiculite serve only as a general guide because of variations in application, quantity, source, and other factors. According to Moeller (2006) prices for U.S. vermiculite concentrate, ex-plant, ranged from $95 to $190 per metric ton, depending on sized grades.

The average unit value of U.S. exfoliated vermiculite sold or used by producers, using actual and estimated data, was about $410 per ton, which was a composite value that included exfoliated vermiculite produced from both U.S. and imported concentrate (table 1).

Foreign Trade

Trade data for vermiculite concentrate are not collected as a separate category by the U.S. Census Bureau but are included within the basket category "vermiculite, perlite, and chlorite, unexpanded" under Harmonized Tariff Schedule of the United States, code 2530.10.0000. According to the Journal of Commerce Port Import/Export Reporting Service, total U.S. imports of vermiculite in 2005 (excluding Canada and Mexico) were about 90,900 t (Commonwealth Business Media, Inc., 2005§). South Africa supplied 53% of the tonnage, and China, 46%.

Outlook

Prices for U.S. vermiculite concentrate may increase in 2006 because of increased energy and transportation costs. Worldwide production capacity continues to outpace consumption, which could limit price increases in the future (Moeller, 2006). New products for waste treatment and disposal may create new markets for vermiculite. Research could be performed to find uses of both vermiculite concentrate and exfoliated vermiculite in organic and inorganic chemical treatment, toxic waste treatment, and other uses (Hindman, 2006).

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TABLE 1
SALIENT VERMICULITE STATISTICS[1]

(Thousand metric tons and thousand dollars unless otherwise specified)

	2001	2002	2003	2004	2005
United States:					
Production:[2]					
Concentrate[e]	110	100	110	100 [3]	100
Exfoliated:[e]					
Quantity	140	115	95	90	85
Value[e]	48,000	44,900	34,800	35,400	35,100
Average value[e, 4] dollars per metric ton	340	390	370	390	410
Exports[e]	7	10	15	10	5
Imports for consumption[5]	65	56	37	69 [e]	91
World, production[6]	431	498	491	516 [r]	527

[e]Estimated. [r]Revised.

[1]Data are rounded to no more than three significant digits.

[2]Sold or used by producers.

[3]Dickson, Ted, 2006, Vermiculite, countries and commodities reports, accessed March 17, 2006, via URL http://www.mining-journal.com.

[4]Based on rounded data.

[5]Source: Commonwealth Business Media, Inc., 2005.

[6]Excludes production by countries for which data were not available.

TABLE 2
ACTIVE VERMICULITE EXFOLIATION PLANTS IN THE UNITED STATES IN 2005

Company	County	State
Isolatek International, Inc.	Sussex	New Jersey.
J.P. Austin Associates, Inc.	Beaver	Pennsylvania.
Palmetto Vermiculite Co., Inc.	Spartanburg	South Carolina.
P.V.P. Industries, Inc.	Trumbull	Ohio.
Schundler Co., The	Middlesex	New Jersey.
Southwest Vermiculite Co., Inc.	Bernalillo	New Mexico.
Sun Gro Horticulture, Inc.	Jefferson	Arkansas.
Do.	La Salle	Illinois.
Thermal Ceramics Inc.	Macoupin	Do.
Thermo-O-Rock East, Inc.	Washington	Pennsylvania.
Thermo-O-Rock West, Inc.	Maricopa	Arizona.
Verlite Co.	Hillsborough	Florida.
Vermiculite Industrial Corp.	Allegheny	Pennsylvania.
Whittemore Co., Inc.	Essex	Massachusetts.
W.R. Grace & Co.	Maricopa	Arizona.
Do.	Broward	Florida.
Do.	Greenville	South Carolina.

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TABLE 3
ESTIMATED EXFOLIATED VERMICULITE SOLD OR USED IN THE UNITED STATES, BY END USE[1]

(Metric tons)

	2004	2005
Aggregates[2]	24,300	22,300
Insulation[3]	W	W
Agricultural:		
Horticultural	22,200	24,600
Soil conditioning	22,800	W
Fertilizer carrier	W	W
Total	W	W
Other[4]	9,830	12,500
Grand total[5]	90,000	85,000

W Withheld to avoid disclosing company proprietary data; included in "Grand total."

[1]Data rounded to no more than three significant digits; may not add to totals shown.

[2]Includes concrete, plaster, and premixes (acoustic insulation, fireproofing, and texturizing uses).

[3]Includes loose-fill, block, and other (high-temperature and packing insulation and sealants).

[4]Includes various industrial and other uses not specified.

[5]Rounded to two significant digits because of estimated data.

TABLE 4
VERMICULITE: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2001	2002	2003	2004	2005[e]
Argentina	1,110	1,105	1,124	1,293 [r]	1,300
Australia[e]	12,000	12,000	12,000	12,000	12,000
Brazil, concentrate	21,464	22,577	26,055	28,700 [r]	30,000 [p, 3]
China[e]	70,000	80,000	90,000	100,000	100,000
Egypt[e]	12,000	12,000	12,000	12,000	12,000
India[e]	4,300	4,300	4,400	4,400	4,500
Japan[e]	6,400	6,200	6,200	6,000	6,000
Malawi	1	-- [r]	-- [r]	-- [r]	-- [3]
Russia[e]	25,000	25,000	25,000	25,000	25,000
South Africa	156,632	210,297	182,802	196,893 [r]	209,801 [p, 3]
Uganda	220	664	1,724	2,688 [r]	3,100 [3]
United States, concentrate, sold and used by producers[e]	110,000	100,000	110,000	100,000 [4]	100,000
Zimbabwe	11,632	23,803	20,016	27,150	23,045 [p, 3]
Total	431,000	498,000	491,000	516,000 [r]	527,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Excludes production by countries for which data are not available and for which general information is inadequate for formulation of reliable estimates. Table includes data available through July 17, 2006.

[3]Reported figure.

[4]Dickson, Ted, 2006, Vermiculite, countries and commodities reports, accessed March 17, 2006, via URL http://www.mining-journal.com.

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WOLLASTONITE

By Robert L. Virta

Domestic survey data were prepared by Hoa P. Phamdang, statistical assistant.

Wollastonite was mined by two companies in the United States in 2005. While mine production is withheld to avoid revealing company proprietary data, industry experts estimate U.S. production to be between 115,000 and 127,000 metric tons per year (t/yr). In 2005, exports of wollastonite were estimated to be less than 10,000 metric tons (t) and imports were estimated to be between 5,500 and 6,500 t. World sales of refined wollastonite products were estimated to be in the range of 500,000 to 550,000 t.

Wollastonite, a calcium metasilicate ($CaSiO_3$), has an ideal composition of 48.3% calcium oxide and 51.7% silicon dioxide but may contain trace to minor amounts of aluminum, iron, magnesium, manganese, potassium, and sodium. It occurs as prismatic crystals that break into massive-to-acicular fragments. Acicular fragments are desirable for filler and extender applications because the long, thin particles improve the flexural modulus, sag resistance, flexural and tensile strengths, and thixotropic properties of the paints, plastics, and rubber products in which they are used. Wollastonite is usually white but also may be gray, brown, or red depending on its composition and grain size. Most commercially mined wollastonite is white in color to meet customers' specifications.

Wollastonite forms when impure limestones are metamorphosed (subjected to heat and pressure) or silica-bearing fluids are introduced into calcareous sediments during metamorphism. In both cases, calcite reacts with silica to produce wollastonite and carbon dioxide. Wollastonite also can crystallize directly from a magma that has high carbon content, but this is a less common occurrence. Deposits of wollastonite have been found in Arizona, California, Idaho, Nevada, New Mexico, New York, and Utah. These deposits also may contain calcite, diopside, garnet, idocrase, and quartz as minor components. New York is the only State where large-scale wollastonite mining has taken place.

Wollastonite is used primarily in ceramics, friction products (primarily automobile brakes), metallurgy, paint, and plastics. Some of the properties that make it so useful are its high brightness and whiteness, low moisture and oil absorption, low volatile content, and the acicular nature of some wollastonite.

Production

Wollastonite has been mined commercially in California and New York. The California deposits, which are in Inyo, Kern, and Riverside Counties, were mined between 1930 and 1970. These operations were limited in size, producing only a few thousand metric tons per year for ceramics, decorative stone, paint, and mineral wool production before closing.

Wollastonite deposits in New York have been mined for more than 50 years. Two companies mined wollastonite in 2005—NYCO Minerals Inc. (a subsidiary of Fording Canadian Coal Trust), which operated mines in Essex County, and R.T. Vanderbilt Co. Inc., which operated a mine in Lewis County. The NYCO deposit contains wollastonite, garnet, and diopside. Parts of the deposit contain up to 60% wollastonite. The ore is processed at the Willsboro, NY, plant, where the garnet is removed by using high-intensity magnetic separators. NYCO also chemically modifies the surfaces of some of its wollastonite products to improve their performance. The R.T. Vanderbilt deposit consists primarily of wollastonite as well as minor amounts of calcite and prehnite and trace amounts of diopside. The ore is processed at R.T. Vanderbilt's St. Lawrence County plant, where it is milled and air classified. R.T. Vanderbilt also produces some surface-treated products.

In 2005, domestic wollastonite production increased from that of 2004. Data collected by the U.S. Geological Survey (USGS) are withheld to avoid disclosing proprietary information. Hawley (2004) estimated U.S. wollastonite production to be between 115,000 and 127,000 t/yr.

Consumption

The USGS does not collect end use data on wollastonite, but market estimates occasionally are published in trade journals. Plastics were believed to have accounted for an estimated 37% of U.S. sales, followed by ceramics (28%), metallurgical applications (10%), paint (10%), friction products (9%), and miscellaneous (6%) in 1999 (Industrial Minerals, 1999). In 2001, ceramic applications were thought to account for 40% to 50% of wollastonite sales worldwide, followed by polymers (20% to 25% of sales), and coatings (10% to 15% of sales). The remaining sales were for construction, friction products, and metallurgical applications (Kendall, 2001).

In ceramics, wollastonite decreases shrinkage and gas evolution during firing, increases green and fired strength, maintains its brightness during firing, permits fast firing, and reduces crazing, cracking, and glaze defects. In metallurgical applications, wollastonite serves as a flux for welding, a source for calcium oxide, a slag conditioner, and to protect the surface of molten metal during the continuous casting of steel. As an additive in paint, it improves the durability of the paint film, acts as a pH buffer, improves its resistance to weathering, reduces gloss, reduces pigment consumption, and acts as a flatting and suspending agent. In plastics, it improves tensile and flexural strength, reduces resin consumption, and improves thermal and dimensional stability at elevated temperatures. Surface treatments are used to improve the adhesion between the wollastonite and the polymers to which it is added. As a substitute for asbestos in floor tiles, friction products, insulating board and panels, paint, plastics, and roofing products, wollastonite is resistant to chemical attack, inert, stable at high temperatures, and improves flexural and tensile strength (Roskill Information Services Ltd., 1996, p. 58-59, 78-81, 104-107, 119, 123-128).

NYCO indicated that sales in 2005 from its operations in Mexico and the United States were 90,000 t valued at $34.9 million compared with 82,000 t valued at $34.8 million in 2004 (Fording Canadian Coal Trust, 2006, p. 5).

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Prices

Prices for wollastonite ranged from $50 to $60 per metric ton for Chinese powder to $1,700 per ton for ultrafine surface-treated wollastonite (Hawley, 2004). Prices for domestically produced acicular wollastonite, ex works, were $205 per ton for 200-mesh, $248 per ton for 325-mesh, and $275 per ton for 400-mesh. The price, ex works, for acicular, high-aspect-ratio wollastonite was $345 per ton. Prices for wollastonite from China, free on board (f.o.b.), in bulk, were $80 to $100 per ton for 200-mesh and $90 to $110 per ton for 325-mesh (Industrial Minerals, 2005a). Quoted prices should be used only as a guideline because actual prices depend on the terms of the contract between the seller and the buyer.

Foreign Trade

Comprehensive trade data were not available for wollastonite. Exports were estimated to be less than 10,000 t in 2005. Imports were estimated to be between 5,500 and 6,500 t in 2005. The United States imported 4,630 t from China, 744 t from India, 77 t from Finland, 75 t from Mexico, 19 t from Spain, and 18 t from Canada, based on data from the Journal of Commerce Port Import/Export Reporting Service. Additional amounts of wollastonite probably were imported from or transshipped through Canada and Mexico.

World Industry Structure

World production of crude wollastonite ore probably exceeded 600,000 t in 2005 but sales of refined wollastonite products were thought to be in the range of 500,000 to 550,000 t.

China was the leading producer of wollastonite with an estimated production of 395,000 t and exports of 190,000 t (Industrial Minerals, 2005b). The next leading producer was India with 169,000 t of production in 2005, almost unchanged from 176,000 t in 2003 (Department of Mines and Geology, 2005§[1]). India was followed by the United States (estimated to be 115,000 to 127,000 t/yr). Production in Mexico was estimated to be 27,100 t in 2005, a decline from 28,200 t in 2004 (Secretaria de Economia, 2005§). Production in Finland was 16,800 t in 2004, a decline from 17,400 t in 2002 (Geological Survey of Finland, 2005§). Small amounts of wollastonite probably were produced in other countries.

World Review

China.—S&B Industrial Minerals SA and Quarzwerke GmbH formed a joint venture with a Chinese partner. The venture, Orykton, will mine and process wollastonite in Liaoning Province. Output will include high-value acicular grades for domestic use and export (Industrial Minerals, 2005b).

Outlook

North American wollastonite producers continue to place greater emphasis on sales of higher value acicular and surface-treated products. The most promising growth area for domestic producers continues to be in plastics. Sales of wollastonite for friction product and automotive plastic applications probably will increase slightly based on the strength of the automobile sales. Sales to ceramics, paint, and steel markets are expected to remain unchanged. Imports of wollastonite also may decline slightly because of increased prices for Chinese wollastonite and the increased cost of transportation from China. China has been the major source of lower value wollastonite grades imported into the United States during the past few years. Worldwide consumption probably will increase slowly as consuming markets expand in response to population growth.

[1]References that include a section mark (§) are found in the Internet References Cited section.

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ZEOLITES

By Robert L. Virta

Domestic survey data and table were prepared by Hoa P. Phamdang, statistical assistant.

In 2005, natural zeolites were mined and processed by 10 companies in the United States. Mine production was 65,500 metric tons (t), and U.S. consumption was 58,000 t. Major markets were in animal feed, water purification, and pet litter applications and accounted for more than 70% of domestic consumption. Exports were estimated to be between 3,000 and 7,000 t, and imports of natural zeolite (other than gem-quality) were estimated to be between 500 and 1,000 t. World production was estimated to be in the range of 2.5 million to 3 million metric tons (Mt).

Zeolites are hydrated aluminosilicates of the alkaline and alkaline-earth metals. About 40 natural zeolites have been identified during the past 200 years; the most common are analcime, chabazite, clinoptilolite, erionite, ferrierite, heulandite, laumontite, mordenite, and phillipsite. The most commonly mined varieties of natural zeolites are clinoptilolite and chabazite. More than 150 zeolites have been synthesized; the most common are zeolites A, X, Y, and ZMS 5. Natural and synthetic zeolites are used commercially because of their unique absorption, catalytic, ion exchange, and molecular sieve properties.

Commercial zeolite deposits in the United States are associated with the alteration of volcanic tuffs in alkaline lake deposits and open hydrologic systems. Commercial deposits in the United States are in Arizona, California, Idaho, Nevada, New Mexico, Oregon, Texas, Utah, and Wyoming. Zeolites in these deposits are chabazite, clinoptilolite, erionite, mordenite, and phillipsite. Other components, such as orthoclase and plagioclase feldspars, montmorillonite, opal, quartz, and volcanic glass, are present in some deposits.

Production

Conventional open pit mining techniques are used to mine natural zeolites. The overburden is removed to allow access to the ore. The ore may be blasted or stripped for processing by using front-end loaders or tractors equipped with ripper blades. In processing, the ore is crushed, dried, and milled. The milled ore may be air-classified based on particle size and shipped in bags or bulk. The crushed product may be screened to remove fine material when a granular product is required, and some pelletized products are produced from fine material. Producers also may modify the properties of the zeolite or blend their zeolite products with other materials before sale to enhance their performance.

Domestic data for natural zeolites were collected by means of a voluntary survey of the domestic mining industry. Survey forms were sent to 11 companies, and 9 responded. Responses accounted for 96% of the production and end-use data.

Ten companies mined natural zeolites in the United States in 2005. One other company did not mine zeolites during the year but sold from stocks or purchased zeolites from other producers for resale (table 1). Chabazite was mined in Arizona, and clinoptilolite was mined and processed in California, Idaho, Nevada, New Mexico, Oregon, Texas, and Wyoming. New Mexico was the leading producer State. Domestic production of zeolites was 65,500 t compared with an estimated 57,400 t of production in 2004.

Bear River Zeolite Co. (BRZ) (a subsidiary of United States Antimony Corporation, Thompson Falls, MT) agreed to provide 3,000 metric tons per month of zeolite to an unspecified purchaser in the concrete industry. The purchaser will provide $1 million to allow Bear River to construct a grinding circuit at its Preston, ID, plant for this product. Production and processing are to start in 2006 (United States Antimony Corporation, 2005).

Consumption

Approximately 58,000 t of natural zeolite was sold in 2005 in the United States compared with an estimated 49,100 t in 2004. Domestic uses for natural zeolite were, in decreasing order by tonnage, animal feed, water purification, pet litter, fungicide or pesticide carrier, horticultural applications (soil conditioners and growth media), desiccant, odor control, oil absorbent, gas absorbent, wastewater cleanup, aquaculture, and catalyst. Animal feed, pet litter, and water purification applications accounted for more than 70% of the domestic sales tonnage. Sales in all except two end-use categories increased. The largest increases in tonnage sales were for animal feed, fungicide and pesticide carriers, and water purification applications. The largest decline in tonnage sales was for pet litter.

Prices

Prices for natural zeolite vary with zeolite content and processing. Unit values, obtained through the U.S. Geological Survey canvass of domestic zeolite producers, ranged from $50 to $140 per metric ton. The bulk of the tonnage sold ranged from $80 and $140 per ton. Eyde and Holmes (2006, p. 1058) reported that prices for industrial or agricultural applications ranged from $30 to $70 per ton for granular products down to 40 mesh and from $50 to $120 per ton for finer (-40 to +325 mesh) ground material. For such products as pet litter, fish tank media, or odor control applications, prices ranged from $0.50 to $4.50 per kilogram. Quoted prices should be used only as a guideline because actual prices depend on the terms of the contract between seller and buyer.

Foreign Trade

Comprehensive trade data are not available for natural zeolites. Exports were estimated to be between 3,000 and 7,000

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t. Imports of natural zeolites (other than gem-quality) were estimated to be between 500 and 1,000 t in 2005. The bulk of the U.S. zeolite trade was in synthetic zeolite products.

World Industry Structure

World production of natural zeolite was estimated to be between 2.5 and 3 Mt based on reported production by some countries and production estimates published in trade journals. Estimates for individual countries were China, 1.5 to 2.0 Mt; the Republic of Korea, 150,000 t; Japan, 140,000 to 160,000 t; the United States, 65,500 t; Cuba, 37,500 t; Hungary and Turkey, 30,000 t each; Slovakia, 25,000 t; New Zealand, more than 18,000 t; Bulgaria and South Africa, 15,000 t each; Australia, 10,000 to 12,000 t; Georgia, 6,000 t; Canada, Italy, and the Commonwealth of Independent States, 4,000 t each; Greece, 3,000 t; and Ecuador, 2,070 t. Small amounts of natural zeolite also were produced in Indonesia.

In general, countries mining large tonnages of zeolite often have substituted zeolite-containing tuffs for various applications. Natural zeolites were used in large quantities for such applications as dimension stone (as an altered volcanic tuff), lightweight aggregate, pozzolanic cement, and soil conditioners. In these cases, the ready availability of zeolite-rich rock at low cost and the shortage of competing minerals and rocks are probably the most important factors for its large-scale use. Also, it is likely that a significant percentage of the material sold as zeolite in some countries is ground or sawn volcanic tuff that contains only a small amount of zeolite.

World Review

Australia and Southeast Asia.—Major uses for zeolites in the Australasian region were in aquaculture, livestock feed, and waste water treatment. Marketing of zeolites in Australia focused on stock feed additives and waste water treatment. In Indonesia, the primary market was aquaculture for prawn farming. Natural zeolites produced in New Zealand were less specialized with sales for absorbents, horticulture, poultry and stock feed additives, and waste water treatment. Three companies mined zeolites in Australia—Envirozel Ltd., Supersorb Minerals NL, and Castle Mountain Enterprises Ltd. Envirozel marketed mainly for agriculture, animal nutrition, and water treatment and purification applications. Supersorb Minerals marketed its zeolites as absorbents for horticultural uses. With combined sales of 10,000 to 12,000 t, growth was expected to be slow. With water shortages in parts of Australia, zeolites were used to purify gray water (water drained from baths, showers, sinks, and washing machines) so prospects were encouraging. NZ Natural Zeolite (a division of Resource Refineries Ltd.) was the only major producer in New Zealand. The company marketed mainly absorbents for animal litter and hazardous chemical spill applications but had developed paper filler grades, stock feed additives, soil amendments, and water treatment products. Production at NZ Natural Zeolite exceeded 18,000 metric tons per year (Hill, 2005).

Canada.—C_2C Zeolite Corp. of Peachland, British Columbia, agreed to acquire 100 hectares of zeolite mining claims near Kamloops, British Columbia. C_2C Zeolite also has staked another 240 hectares adjacent to the Kamloops claims. The zeolite in the deposit is chabazite with potential uses in desiccant and catalysis applications and for purification of oxygen, argon, and hydrogen (Canadian Institute of Mining, Metallurgy and Petroleum, 2005§[1]).

Zeo-Tech Enviro Corp., Vancouver, British Columbia, announced that it had completed drilling, blasting, and crushing 10,000 t of zeolites at its mine (Zeo-Tech Enviro Corp., 2005). United Zeolite Products Ltd. (UZP) (a joint venture between Zeo-Tech, C_2C, Thelon Ventures Ltd. of Vancouver, British Columbia, and First American Scientific Corp. of Delta, British Columbia) completed construction and testing of its processing plant in Princeton, British Columbia (Thelon Ventures Ltd., 2005). UZP was contracted to supply Halliburton Group Canada micronized zeolite for use in gas- and oil-well cementing systems.

Outlook

Production and sales of natural zeolites continue to make a slow climb as recognition of their versatility has increased. Starting from a few hundred tons with no sustained production in the mid-1970s, zeolite production increased to 65,500 t in 2005. There was a rapid rise in production with the opening of a major zeolite mine in the early 1990s. This, however, was followed by a sharp decline in production, ending in 1997, as supply outstripped demand. The ratio of production to consumption in 1994 was 1.5, contrasting with a more typical 1.15 to 1.25 observed in prior years. Since then, production has more closely mirrored consumption, showing only a little variability from year to year.

Historically, pet litter was the dominant market for natural zeolites, accounting for more than 50% of sales through 1995. Sales to animal feed and horticulture markets began to increase around 1994, growing to claim a significant portion of sales by 1997. Other markets, such as aquaculture, desiccant, and wastewater cleanup, were developed but remained as minor markets. Around 2002, interest in the use of natural zeolites for water treatment began to increase, particularly in Canada, and this market has grown considerably. In 2005, reported sales for water treatment (for municipal water treatment and pool filtration) surpassed that for pet litter and became the second ranked market after animal feed applications, which became the leading market for natural zeolites in 2004.

This progress in marketing natural zeolites is encouraging, given that natural zeolites have been considered to be a commodity of great potential since the industry's beginning in the late 1960s. Also encouraging is the continued development through surface treatment and ion exchange of zeolite products and the opening of new markets, such as lightweight aggregate for specialty concrete products. Based on trends of the past 10 years, production and sales of natural zeolites probably will increase by at least 4% to 5% per year for the next 2 to 3 years.

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TABLE 1
DOMESTIC ZEOLITE PRODUCERS AND SUPPLIERS IN 2005

State and company	Type of zeolite
Arizona:	
GSA Resources, Inc.	Chabazite.
UOP Inc.	Do.
California:	
Ash Meadows Zeolite, LLC	Clinoptilolite.
KMI Zeolite, Inc.	Do.
Idaho:	
Bear River Zeolite, LLC	Do.
Steelhead Specialty Minerals, Inc.	Do.
Teague Mineral Products Co.	Do.
Nevada, Moltan Co.	Chabazite/mordenite.
New Mexico, St. Cloud Mining Co.	Clinoptilolite.
Texas, Zeotech Corp.	Do.
Wyoming, Addwest Minerals International Ltd.	Do.

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Zinc

By Xiaoyu Bi

World review written by Grecia R. Matos. Domestic survey data and tables were prepared by Samir Hakim, statistical assistant, and the world production tables were prepared by Regina R. Coleman, international data coordinator.

In 2005, domestic zinc mine production, expressed in zinc content of ore, increased slightly compared with that of 2004, according to the U.S. Geological Survey (USGS). Based on recoverable content of concentrate and annual average U.S. price, the value of zinc mine production was estimated to be about $1.07 billion, 29% greater than that of 2004. By yearend 2005, only seven mines in four States were operating in the United States. Mine closures in the past 3 years solidified Alaska's position as the leading producer of zinc concentrate, followed by Missouri, Washington, and Montana in descending order. In 2005, as in every year since the opening of Alaska's Red Dog Mine in 1989, U.S. mine production greatly exceeded smelter capacity. Zinc mine production data were obtained by the USGS from a voluntary survey of domestic mining operations. The "Lode Mine Production" survey was sent to 20 zinc mining operations, all of whom responded to the request for production data shown in tables 1 and 2.

Concentrates were exported and refined zinc metal imported (tables 1, 6). Most of the zinc concentrate (73%) was exported to four countries—Canada, the Republic of Korea, Japan, and Spain, in descending order (table 14). Zinc metal production in the United States, which was provided by 2 primary smelters and 12 large- and medium-size secondary smelters, increased by about 2% in 2005 (table 1, 4). Zinc metal imports (zinc metal, all grades; unalloyed and unwrought) were primarily from Canada and Mexico.

Apparent domestic consumption of refined zinc metal decreased 19% to about 939,000 metric tons (t). About one-half of metal consumed in the United States was used for galvanizing, followed by use in zinc-base alloys and brass and bronze (table 11). The agriculture, chemical, paint, and rubber industries were the primary users of zinc compounds and dust.

The average U.S. producer price for Special High Grade zinc in 2005, which was based on the London Metal Exchange (LME) daily cash price plus premium, increased by about 28% to $1.48 per kilogram (67.11 cents per pound) (table 1).

Worldwide shortages of zinc-in-concentrate further restricted the supply of refined zinc. Chinese apparent consumption of zinc was 14% higher than that of 2004, whereas U.S. consumption of zinc metal was 17% lower. Countries in Europe and North and South America account for less than one-half of global zinc output. Chinese output of zinc metal increased by 6% in the first 11 months of 2005, topping 2.7 million metric tons (Mt) for the year, and China continued to be a net importer of zinc metal. Estimated shortfall of production as compared with consumption was expected to be almost 200,000 t for 2005 (Metal-Pages, 2006b§[1]).

Legislation and Government Programs

A stockpile of zinc for national defense purposes has been maintained for more than 60 years. In 1992, Public Law 102-484 was signed, which authorized the disposal of the entire inventory of zinc from the National Defense Stockpile (NDS). The basic ordering agreement (BOA) under which zinc is currently sold from the NDS was established in May 2002. In April 2004, the BOA was amended to establish a minimum quote for an award of 20 t unless a smaller quantity was all that was available. Additionally, the Government changed its right to vary the quantity or weight delivered from that in the original bid to 5% from 2% on deliveries with a contract price adjustment to be made on the actual delivered zinc.

The Defense Logistics Agency (DLA), which maintains the NDS, was authorized to sell 45,000 t of zinc in fiscal year 2005 (October 1, 2004, to September 30, 2005). The stockpile inventory on December 31, 2004, was 68,000 t, while the inventory at yearend 2005 was 47,500 t, all of which was authorized for disposal (U.S. Department of Defense, 2005, p. 9).

Production

Mine.—HudBay Minerals Inc., formerly OntZinc Corporation, announced plans to reopen the Balmat Mine in upstate New York. It had been closed since May 2001 owing to low zinc prices. HudBay expected production to commence during the second quarter of 2006, and the mine to be in full production in 2008. Its estimated output of 60,000 metric tons per year (t/yr) of zinc in concentrate would be processed at the Canadian Electrolytic Refinery in Valleyfield, Quebec, Canada, and treated at HudBay's Zochem plant in Brampton, Ontario. Estimated mineral ore reserves amounted to 1,709,000 t grading 11.1% zinc, with focus on mining higher grade ore with a mine life of 7 years. In addition, underground exploration at this mine will likely extend the estimated mine life (Hudbay Minerals Inc., 2006, p. 4, 13).

In 2005, mine production from the Red Dog Mine, AK, increased by about 3% to 568,000 t of zinc compared with 554,000 t produced in 2004. Projected 2006 production of zinc for the Red Dog Mine was 574,000 t. Teck Cominco Ltd.'s Pend Oreille Mine in northeastern Washington State began commercial production in August and by yearend had produced 45,000 t of zinc in concentrates. Pend Oreille's ore reserves were 4.7 Mt grading 7.0% zinc and 1.2% lead and an additional 2.3 Mt of ore containing 6.7% zinc and 1.3% lead was inferred at yearend. Estimated production of zinc for 2006 will probably remain steady (Teck Cominco Limited, 2006, p. 8-9). Zinc sales were 18% lower than 2004, however, operating profit increased

[1]References that include a section mark (§) are found in the Internet References Cited section.

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by $118 million in 2005 owing to higher zinc and lead prices (Teck Cominco Limited, 2006§).

In Missouri, the Doe Run Company maintained the West Fork Mill, reportedly on care-and-maintenance status in 2005, and the Sweetwater lead-zinc mine along with five other active production shafts. Products are shipped by trucks over public roads. As of October 31, 2005, the Doe Run Company reported total (proven and probable) reserves decreased to 34,283 t from 47,686 t in 2003. Higher operating costs accounted for the 28% decline of reserves. The estimated average metallurgical recovery for zinc was 83.0% (Doe Run Company, The, 2006b, p. 21).

Greens Creek Mine in Juneau, AK, operated by Kennecott Greens Creek Mining Co. (a subsidiary of Kennecott Minerals Company) produced concentrates containing gold, lead, silver, and zinc. In 2005, mill production rate was reported to be 1,966 metric tons per day and by yearend, 58,300 t of zinc had been produced. The estimated recoverable zinc in proven and probable reserves was 605,500 t with a projected mine life beyond 10 years (Kennecott Minerals Company, 2006).

In September 2004, CalEnergy Minerals LLC (a subsidiary of MidAmerican Energy Holdings Company) ceased zinc recovery operations at its Salton Sea plant in southern California. Despite recent increases in refined zinc prices, the company reportedly ran up large losses since it began operations in December 2002 (Salton Sea Funding Corporation, 2005, p. 20).

Smelter.—In 2004, a strike at Big River Zinc's Sauget, IL, refinery was averted when a majority of the 220 unionized workers agreed to a 1-year extension to the existing labor agreement, which had been due to expire in May. Big River Zinc (a subsidiary of Korea Zinc Co. Ltd.), was the second largest smelter in the United States that produced about 90,000 t/yr of zinc as refined zinc metal, zinc alloys, zinc powders, zinc sulfate, and zinc oxide. The company also produces electrolytic or commercial grade sulfuric acid and high-purity cadmium oxide (Metal-Pages, 2004§). Big River Zinc's closure was announced by Korea Zinc in December 2005 as the company sought a buyer for the plant (ZincOx Resources plc, 2006, p. 8-9).

Prices

The average LME slab zinc price increased by 32% to $1,381.37 per metric ton from that of 2004 and rose dramatically during the final quarter of the year. Demand between January to November was almost 1% higher than that of the similar period of 2004, which was enough to push the supply demand balance into supply deficit. Inventories held by the LME at yearend 2005 decreased by 37% to 393,550 t from 628,625 t at yearend 2004 (London Metal Exchange Ltd., 2006). Case settlement prices on the LME averaged $1,821.44 per ton in December, making December the highest monthly level for zinc prices since September 2000.

World Review

In 2005, world mine production of zinc was 9.8 Mt about 3.6% more than that in 2004; China, Australia, and Peru, in descending order, accounted for more than one-half of total world mine production. World refined production of zinc was 10.7 Mt, an increase by 2% compared with that in 2004. The leading producing countries, in descending order, were China, Canada, the Republic of Korea, and Japan, accounting for about 47% of total world refined production. According to data compiled by the International Lead and Zinc Study Group, world consumption of refined zinc decreased slightly in 2005 to 10.6 Mt from 10.7 Mt in 2004. China, the United States, Japan, and the Republic of Korea, in decreasing order of metal used, accounted for nearly one-half of the world's zinc consumption. The main end use for zinc, galvanizing (a coating for iron and steel products to increase resistance to rust and corrosion), accounted for about 48% of worldwide zinc use. The most commonly galvanized products were steel sheet and strip, tube and pipe, and wire and wire rope. Worldwide, the automobile industry was the largest user of galvanized steel (International Lead and Zinc Study Group, 2006, p. 40-41).

Australia.—In February, Zinifex Limited (Melbourne) declared a force majeure on zinc concentrate shipments from its open pit Century Mine in northwest Queensland, the world's second leading zinc mine after the Red Dog Mine in Alaska. An electrical fault at the semiautogeneous grinding mill forced closure of the concentration circuit (Mining Journal, 2005). During the 11-day closure, Zinifex lost 17,700 t of contained zinc production and 1,400 t of contained lead production (Metal Bulletin Daily, 2005).

In 2005, annual production at Zinifex's Century Mine declined to 501,000 t from 517,000 t in 2004, and at its underground Rosebery Mine in western Tasmania, production declined to 88,000 t from 92,000 t in 2004. Zinc production for its Hobart Smelter in southern Tasmania was 252,716 t, a significant portion of which was converted into diecast alloy and primarily sold in China; its Port Pirie Smelter in South Australia, mainly a lead smelter, produced 37,068 t of zinc metal (Zinifex Limited, 2006, p. 12).

In May, Terramin Australia Limited (Strathalbyn, Australia) announced that Sempra Metals & Concentrates Corp. (San Diego, CA) and Macquarie Bank Limited (Sydney, Australia) would invest up to $17 million in its Angas Project, which it thought to be South Australia's largest zinc deposit. The funds were to be allocated to drilling, project design and costing, and early capital expenditures, if and when the decision to mine was made. Terramin identified approximately 2.8 Mt of ore resources grading 14.1% zinc equivalent, including 2.1 Mt indicated resources and 0.7 Mt inferred resources (Terramin Australia Limited, 2005a). The company also announced that it had concluded a joint-partnership agreement with Zinifex. Under the agreement, Zinifex would invest up to $A8 million in the Mennennie Dam project for exploration and development and earn up to a 70% share in the joint venture. The project encompasses the largest known lead-zinc and silver deposit in South Australia with almost equal proportions of lead and zinc (Terramin Australia Limited, 2005b).

At Xstrata plc's (Zug, Switzerland) Mount Isa operation in northwest Queensland, production of zinc-in-concentrate increased to 457,122 t in 2005 by 23% from that in 2004, and lead-in-concentrate production increased by 29% to 277,753 t,

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owing to improved operational and maintenance practices and increased ore feed. The Mount Isa Mine had reserves to support a mine life of approximately 11 years. Ore throughput at the Mount Isa zinc concentrator increased to 4.4 Mt, up by 37% from that in 2004. The George Fisher Mine produced 2.6 Mt of ore, 7% more than in 2004. Production increased in the second half of 2005 as a result of better mine planning, updated mining equipment, and improved geotechnical control of stoping. Ore production was expected to increase further in 2006 following improvements in the ore hoisting capacity. In 2004, Xstrata approved the development of the Black Star Mine, to be a zinc-lead open pit operation. The mine was expected to supply an additional 1.5 million metric tons per year (Mt/yr) of ore to supplement current production output from the George Fisher Mine, and from the Mount Isa Mine, with the objective of fully utilizing the capacity of the Mount Isa zinc-lead concentrator (Xstrata plc, 2006b, p. 70-74).

In August 2005, Xstrata plc announced its intention to convert the McArthur River zinc-lead mine in the Northern Territory from an underground to an open pit operation. The open pit conversion would increase ore throughput to 1.8 Mt/yr from 1.6 Mt/yr in order to maintain current levels of concentrate production from declining ore grades and will extend the mine's life by at least 25 years (Xstrata plc., 2005). In August, Xstrata also filed an environmental impact statement (EIS) with the Northern Territory Government, and in December, submitted a supplementary EIS, in response to submissions received as part of the consultation process. In February 2006, the Northern Territory Minister for the Environment and Heritage declined to recommend the approval of Xstrata's proposal (Xstrata plc, 2006b, p. 74). In April 2006, following a review by the Federal Government, Xstrata received approval from the Northern Territory Government to mine the stage B test pit, which would allow Xstrata to remain operational and continue at current production levels until March 2007 while the environmental review process for the full open pit development proceeded (Xstrata plc, 2006a).

Burkina Faso.—Alternative Investment Market (AIM) Resources Limited (Sidney, Australia) planned to develop the first zinc mine in Burkina Faso, West Africa. In December, a bankable feasibility study was released by Snowden Mining Industry Consultants announcing positive results for the high grade Perkoa Zinc Project. AIM was expected to start production by yearend 2007, with ore production of about 6.3 Mt, dry concentrate production of 1.6 Mt, and zinc metal production of 848,390 t. The zinc mine reportedly has reserves to support a mine life of approximately 14 years (AIM Resources Limited, 2005).

Canada.—The United States is the leading customer for Canadian refined zinc, receiving about 462,000 t (88%) of refined zinc (International Lead and Zinc Study Group, 2006, p. 66). In 2005, Noranda Income Fund produced 272,418 t of zinc at its Salaberry-de-Valleyfield, Quebec, zinc refinery, about 2% less than the 277,283 t produced in 2004. In 2005, some domestic mines closed and refining operations began to treat a different mix of concentrates having higher iron and lower zinc content, reducing production in the second half of the year (Noranda Income Fund, 2006).

Teck Cominco Ltd.'s metallurgical operation at Trail, in British Columbia, was one of the world's largest fully integrated zinc and lead smelting and refining complexes. Refined zinc production of 223,200 t was 25% lower than in 2004 as a result of an interruption caused by a 79-day strike by workers represented by the United Steelworkers of America that began on July 19. The strike ended on October 5, when the unions ratified the terms of a new collective agreement covering the 3-year period from June 1, 2005, to May 31, 2008. Following the restart in October, refined zinc production averaged 26,000 metric tons per month in November and December (Teck Cominco Limited, 2006, p. 27).

China.—According to China's General Administration of Customs, China's most notable drop in export volume during 2005 was that of refined zinc, which declined by 45% to 123,252 t compared with exports in 2004. Significant cuts in shipments to major consumers in Hong Kong, the Republic of Korea, and Taiwan more than offset increases elsewhere. Exports of zinc alloy decreased by 39.4% to 23,600 t in 2005 (Metal-Pages, 2006a§). China's concentrate imports decreased by 7.8% to 567,800 t, compared with that in 2004, with declines in deliveries from Australia, India, and Iran offsetting increases from Myanmar, North Korea, and Vietnam. Refined zinc imports increased by 63.8%, to 392,000 t, with most of the increase coming from Australia. Zinc alloy imports rose by 3.9%, to 229,000 t (Metal-Pages, 2006c§).

China's National Bureau of Statistics reported production of 1.8 Mt of zinc-in-concentrate, an increase of 13% compared with 1.6 Mt in 2004. In September, the Bairendaba Silver Polymetallic Mine, located in Hexigten Banner, Chifeng City, Mongolia, was commissioned. The mine was one of the largest nonferrous metal mines in North China, with resources of 1.05 Mt of zinc (Antaike, 2006a). In September, the construction of Tsairt Minerals' Tumurtiin Ovoo Mine near the town of Sukhe Bator, Suhbaatar Province, Mongolia, was completed. The mine was jointly owned by China Nonferrous Metal Industry Engineering Co. Ltd. (51%) and Mentalimpex of Mongolia (49%). The mine had 7.5 Mt of ore reserves with an average grade of 13.67% zinc. The open pit mine was designed to process 300,000 t of ore and will probably produce 66,000 t/yr of zinc in concentrate containing 32,700 t/yr of zinc. The company projected a 25-year open pit operation followed by 10 years of underground mining (Metals Economics Group, 2006, p. 15).

Hunan Zhuye Torch Metal Co., Ltd., the leading zinc smelter in China, produced 326,778 t of zinc in 2005, an increase of 8% compared with that in 2004. In December, Shenzhen Zhongjin Lingnan Nonfemet Co. Ltd., China's third leading zinc producer, was forced to close its Shaoguan Smelter following a toxic spill into the Beijing River. The smelter had the capacity to produce 160,000 to 170,000 t/yr of zinc. After renovating the waste treatment systems and passing an inspection for compliance with government environmental standards, it was to be reopened in early 2006 (Antaike, 2006b; Metal-Pages, 2006d§).

To address the existing problems in China's lead and zinc industry, such as lack of raw materials, outdated technology and equipment, small plant size, and environmental pollution, the National Development and Reform Commission conducted an

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investigation and released a Catalogue for Guidance of Industry Structure Adjustment 2005. According to the catalogue, construction of zinc smelters with capacity less than 100,000 t/yr of zinc, lead smelters with capacity less than 50,000 t/yr of primary lead, and secondary lead smelters with capacity less than 10,000 t/yr of secondary lead will be restricted, and projects adopting backward technologies will be eliminated (Antaike, 2006a, b).

India.—Vedanta Resources plc (London, United Kingdom), managed by Hindustan Zinc Limited (HZL) (Udaipur, India), India's only integrated zinc company, supplied nearly 75% of India's zinc requirements. The production capacity for galvanized steel in India was increasing significantly in response to the high demand for the product in infrastructure and construction work. HZL's zinc operations included three lead-zinc mining complexes, one-lead-zinc smelter, and three smelters. Its total zinc metal output during 2005 was 284,000 t, an increase of 34% compared with that in 2004. HZL's total mine production of zinc-in-concentrate increased by 33% to 472,000 t in 2005, principally owing to increased output from the Rampura Agucha Mine. The mine located in the northern State of Rajasthan was the leading producer (owned 65% by Vedanta and 35% by the Government of India). In May, Vedanta completed a $360 million expansion at the Rampura Agucha Mine and the nearby Chanderiya Smelter. The expansion would increase the production capacity to about 400,000 t/yr from 170,000 t/yr of refined zinc (Vedanta Resources plc, 2006, p. 11-12).

Ireland.—In April, Vancouver-based Lundin Mining Company acquired ARCON International Resources plc (County Kilkenny, Ireland), which owned the Galmoy zinc-lead mine. Combined with its other zinc assets in Sweden, the Zinkgruvan and Storliden Mines, Lundin Mining increased its estimated zinc production to almost 152,000 t/yr. Lundin also announced that it would soon start an aggressive exploration program in County Kilkenny, Ireland (Platts Metals Week, 2005).

Kazakhstan.—In December, the Kazakhstan Government auctioned off a 22.65% stake in Kazzinc JSC (Ust-Kamenogorsk, Republic of Kazakhstan); previously, it sold a 5% stake for $26.3 million to an undisclosed buyer. It was established in 1997 through the merger of three main nonferrous metals companies in eastern Kazakhstan: Ust-Kamenogorsk Lead and Zinc Combinate Smelter, Leninogorsk Polymetallic Combinate Smelter, and Zyrianovsk Lead Combinate Smelter. All three producers were majority owned by the Government of Kazakhstan. Kazzinc produced 287,198 t of refined zinc in 2005, an increase of 17% since 2000 and 66% since 1997, and accounted for about 90% of Central Asia's output of refined zinc (CRU Monitor, 2005a; Kazzinc, 2006§).

Peru.—According to Peru's Ministry of Energy and Mines, production of zinc-in-concentrates in 2005 decreased slightly to 1,201,671 t from 1,209,006 t in 2004, and was down about 12% compared with production in 2003. The Volcan Compañia Minera S.A.A. operated four mineral centers located in the regions of Pasco and Junín, in central Peru, where it produced zinc and lead-silver concentrates. It was the leading zinc producer in Peru in 2005, producing 237,288 t of zinc-in-concentrate. Compañia Minera Antamina S.A. a joint venture between Teck Cominco Ltd. (22.5%), BHP Billiton Ltd. (33.75%), Falconbridge Ltd. (33.75%), and Mitsubishi Ltd. (10%), was Peru's second leading producer, located in the north central Peruvian Andes. Antamina produced 218,265 t of zinc-in-concentrates in 2005, 4% lower than in 2004. Output at the mine is expected to decline by 30% during 2006 because of changes in ore characteristics and grade (CRU Monitor, 2006a). Empresa Minera Los Quenuales S.A., Peru's third leading zinc producer, increased mine production to 191,291 t of zinc, 2% more than in 2004 (Ministerio de Energía y Minas, 2005§).

Peruvian refined zinc production was 163,603 t in 2005, nearly a 16% decrease compared with that in 2004. Sociedad Minera Refinería de Zinc Cajamarquilla S.A. (Group Votorantim Metais S.A., 99%, and employees, 1%) produced 122,424 t, about three-quarters of the Peruvian refined zinc in 2005; the remaining 41,179 t was produced by the Doe Run Peru S.R. Ltd. in La Oroya, Junín (Ministerio de Energía y Minas, 2005§). Expansion plans aimed at doubling current refined production at Cajamarquilla were delayed until at least 2008 owing to the tight zinc concentrates market (CRU Monitor, 2006b). At La Oroya lead-zinc-copper smelter, Doe Run Peru expected to complete eight of the nine projects required by the Environmental Adjustment and Management Program (PAMA) by yearend 2009. The final project includes the construction of three sulfuric acid plants. The acid plant for the zinc circuit was expected to be completed by yearend 2006; the lead circuit by 2008; and the copper circuit by yearend 2009. The company was seeking more time to complete an additional project at the metals processing facility. The company's investment in PAMA mandated projects was expected to be $200 million (Doe Run Company, The, 2006a).

Peru exported an estimated 989,000 t of zinc-in-concentrate in 2005, 57,000 t (6%) more than in 2004. This increase did not reflect an increase in the mine production level, which remained essentially the same, but rather displaced concentrate from La Oroya smelter, which had reduced its operating rates to 45,000 t/yr from 80,000 t/yr in December 2004 in order to reduce emissions of sulfur dioxide (CRU Monitor, 2006b).

Current Research and Technology

ZincOx Resources' Big River Zinc (BRZ) project replaces the Mid-West Recycling Project which was previously planned for the company's recycling strategy in North America. Treatment of electronic arc furnace dust (EAFD) at BRZ will require construction of a new leach and purification plant. The company entered into a strategic alliance with Envirosafe Services of Ohio, Inc. (ESOI), a specialist hazardous waste disposal company, to recover zinc from EAFD. Under the agreement, ESOI will be responsible for properly managing the delivery of EAFD to BRZ, the stabilization of residue, removal from site, and final disposal. A cost estimate and feasibility study was expected to be completed during the third quarter of 2006 (ZincOx Resources plc, 2006, p. 3, 9).

The Japan Science and Technology Agency along with researchers from the Tokyo Institute of Technology developed a transistor made from an oxide of indium, gallium, and zinc

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allowing for flexible displays. The compound oxide is applied as a thin film on plastic allowing the transistor to be transparent and flexible (Metal-Pages, 2005a§).

An inexpensive blue light-emitting diode (LED) containing zinc oxide instead of indium gallium nitride or silicon carbide was developed by a research team at the Institute for Materials Research in Japan. The main use of blue LEDs is for back light in electronic devices such as mobile telephones and lasers in digital video disc (DVD) players. The zinc oxide containing LEDs are high-quality, undoped p-type zinc oxide films, which were expected to lower manufacturing costs for blue LEDs and promote developments in high-quality DVDs (Metals-Pages, 2005b§).

Outlook

According to the International Lead and Zinc Study Group (2006§), world consumption for refined zinc metal was expected to rise by about 4.8% to 11.2 Mt in 2006. World mine output was expected to be 4.5% higher than that of 2005 as European output would benefit from production increases in Greece, Ireland, Kazakhstan, Russia, and Sweden, all of which were expected to rise by 8%. World refined zinc metal output was expected to be about 10.7 Mt in 2006. Production increases in Australia, Belgium, Canada, China, India, Kazakhstan, the Republic of Korea, and Netherlands were expected to fuel this 4.3% rise. Overall, a supply deficit of 437,000 t of refined zinc was expected in 2006. This imbalance could result in continued zinc price increases.

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TABLE 1
SALIENT ZINC STATISTICS[1]

		2001	2002	2003	2004	2005
United States:						
Production:						
Domestic ores, contained zinc	metric tons	842,000	780,000	768,000	739,000	748,000
Domestic ores, recoverable zinc	do.	799,000	701,000	738,000	715,000	720,000
Value, recoverable zinc	thousands	$774,000	$664,000	$661,000	$827,000	$1,070,000 e
Refined zinc:						
From domestic ores	metric tons	169,000	151,000	155,000	156,000	159,000
From foreign ores	do.	34,000	30,800	31,900	32,200	32,100
From scrap	do.	108,000	113,000	116,000	117,000	118,000
Total	do.	311,000	294,000	303,000	305,000	310,000
Secondary zinc[2]	do.	267,000	253,000	265,000	241,000	231,000
Exports:						
Ores and concentrates, zinc content	do.	696,000	822,000	841,000	745,000	786,000
Slab zinc	do.	1,180	1,160	1,680	3,300	785
Rolled zinc	do.	5,700	7,200	9,430	9,770	8,760
Imports for consumption:						
Ores and concentrates, zinc content	do.	84,000	122,000	164,000	231,000	156,000
Refined (slab) zinc	do.	813,000	874,000	758,000	812,000	668,000
Rolled zinc	do.	7,240	1,640	1,790	2,500	3,630
Stocks of slab zinc, December 31:						
Producer	do.	7,380	8,550	7,660	6,430	5,670
Consumer	do.	57,100	59,100	55,300	56,300	55,100
Merchant	do.	10,300	9,970	10,300	10,200	10,200
Total	do.	74,700	77,600	73,300	73,000	71,000
Government stockpile	do.	120,000	109,000	95,200	66,400	46,000
Consumption, refined zinc:						
Reported	do.	543,000	496,000	506,000	510,000	499,000
Apparent[3]	do.	1,150,000	1,170,000	1,080,000	1,160,000	939,000
All classes[4]	do.	1,420,000	1,420,000	1,340,000	1,400,000	1,170,000
Price, special high grade	cents per pound	43.96	38.64	40.63	52.47	67.11
World:						
Production:						
Mine	thousand metric tons	8,930 r	8,550 r	9,470 r	9,460 r	9,800
Smelter	do.	9,320 r	9,720 r	9,900 r	10,400 r	10,700
Price, London Metal Exchange	cents per pound	40.16	35.31	37.53	47.51	62.66

eEstimated. rRevised.

[1]Data are rounded to no more than three significant digits, except prices; may not add to totals shown.

[2]Zinc in metal products and compounds derived directly from scrap; refined secondary zinc is listed separately in the table.

[3]Domestic production plus net imports, plus or minus stock changes.

[4]Apparent consumption of refined zinc plus reported consumption of zinc in metal products and compounds derived directly from ore, concentrate, or scrap.

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TABLE 2
MINE PRODUCTION OF RECOVERABLE ZINC
IN THE UNITED STATES, BY STATE[1]

(Metric tons)

State	2004	2005
Alaska[2]	630,000	628,000
Missouri	40,400	34,200
Montana	14,800	12,500
Other[3]	29,400	45,300
Total	715,000	720,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Data based, in part, on publicly available information.
[3]Includes production from Idaho, Tennessee, and Washington.

TABLE 3
LEADING ZINC-PRODUCING MINES IN THE UNITED STATES IN 2005, IN ORDER OF OUTPUT

Rank	Mine	County and State	Operator	Source of zinc
1	Red Dog	Northwest Arctic, AK	Teck Cominco Alaska Inc.	Lead-zinc ore.
2	Greens Creek	Juneau, AK	Kennecott Greens Creek Mining Co.	Zinc ore.
3	Pend Oreille	Pend Oreille, WA	Teck Cominco American Inc.	Lead-zinc ore.
4	Brushy Creek	Reynolds, MO	Doe Run Resources Corp.	Lead ore.
5	Montana Tunnels	Jefferson, MT	Apollo Gold Corp.	Gold ore.
6	Buick	Iron, MO	Doe Run Resources Corp.	Lead ore.
7	Viburnum (#28 and #35)	do.	do.	Do.

TABLE 4
REFINED ZINC PRODUCED IN THE UNITED STATES[1]

(Metric tons)

	2004	2005
Primary:		
From domestic ores	156,000	159,000
From foreign ores	32,200	32,100
Total	189,000	191,000
Secondary	117,000	118,000
Grand total[2]	305,000	310,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Excludes zinc recovered by remelting.

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TABLE 5
REFINED ZINC PRODUCED IN THE UNITED STATES, BY GRADE[1]

(Metric tons)

Grade	2004	2005
Special high	94,600	94,800
Continuous galvanizing	108,000	110,000
Other[2]	102,000	105,000
Total	305,000	310,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes controlled lead, high, and prime western grades.

TABLE 6
SLAB ZINC CAPACITY OF PRIMARY ZINC PLANTS IN THE UNITED STATES, BY TYPE OF PLANT AND COMPANY

(Metric tons)

Type of plant and company	2004	2005
Electrolytic:		
Big River Zinc Corp., Sauget, IL	100,000	100,000
Pasminco Ltd., Clarksville, TN	115,000	115,000
Electrothermic, Zinc Corporation of America, Monaca, PA	--	--
Total	215,000	215,000

-- Zero.

TABLE 7
STOCKS AND CONSUMPTION OF NEW AND OLD ZINC SCRAP IN THE UNITED STATES IN 2005, BY TYPE OF SCRAP[1]

(Metric tons, zinc content)

		Consumption				
Type of scrap	Stocks, January 1	Receipts	New scrap	Old scrap	Total	Stocks, December 31
Diecastings	W	W	--	W	W	185
Flue dust	341	69,000	34,500	34,500	69,000	341
Galvanizer's dross	2,830	41,000	41,000	--	41,000	2,830
Old zinc[2]	102	253	--	276	276	79
Remelt die-cast slab	W	W	--	W	W	53
Remelt zinc[3]	1,240	47,300	47,300	--	47,300	1,240
Skimmings and ashes[4]	W	22,600	22,300	--	22,300	739
Other[5]	882	15,500	8,530	7,020	15,500	199
Total	5,390 r	196,000	154,000	41,800	195,000	5,660

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other." -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes engraver's plates and rod and die scrap.
[3]Includes new clippings.
[4]Includes slab and die-cast skimmings.
[5]Includes chemical residues and solutions, electrogalvanizing anodes, fragmentized diecastings, and steelmaking dust.

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TABLE 8
PRODUCTION OF ZINC PRODUCTS FROM
ZINC-BASE SCRAP IN THE UNITED STATES[1]

(Metric tons)

Products	2004	2005
Redistilled slab zinc	117,000	120,000
Other zinc metal products[2]	6,930	7,070
Zinc in chemical products	27,500	27,200
Zinc dust	5,020	5,020

[1]Data are rounded to no more than three significant digits.
[2]Includes electrogalvanizing anodes, remelt die-cast slab, and other metal alloys.

TABLE 9
ZINC RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES, BY TYPE OF SCRAP AND FORM OF RECOVERY[1]

(Metric tons)

	2004	2005
Type of scrap:		
New scrap:		
Zinc-base	151,000	149,000
Copper-base	151,000	152,000
Magnesium-base	548	548 e
Total	302,000	302,000
Old scrap:		
Zinc-base	39,900	40,100
Copper-base	6,290	2,060
Aluminum-base	548	548 e
Magnesium-base	338	338 e
Total	47,100	43,100
Grand total	349,000	345,000
Form of recovery:		
Metal:		
Slab zinc	117,000	120,000
Zinc dust	5,020 r	5,020
Total	122,000 r	125,000
In brass and bronze	168,000	168,000
In chemical products:		
Zinc oxide (lead free)	15,600	15,600
Zinc sulfate	22,900	23,100
Miscellaneous[2]	9,550	8,880
Total	217,000	216,000
Grand total	338,000 r	341,000

eEstimated. rRevised.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes chlorine, electrogalvanizing anodes, and zinc content of slab made from remelt die-cast slab.

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TABLE 10
U.S. CONSUMPTION OF ZINC[1]

(Metric tons)

	2004	2005
Refined zinc, apparent	1,160,000	939,000
Ores and concentrates, zinc content	617	617
Secondary, zinc content[2]	241,000	231,000
Total	1,400,000	1,170,000

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Excludes secondary slab zinc and remelt zinc.

TABLE 11
U.S. REPORTED CONSUMPTION OF ZINC IN 2005, BY INDUSTRY USE AND GRADE[1]

(Metric tons)

Industry use	Special high grade	High grade	Prime western	Remelt and other grades	Total
Galvanizing	111,000	22,200	64,700	40,300	238,000
Zinc-base alloys	W	W	W	W	W
Brass and bronze	42,300	W	W	W	83,900
Other	163,000	39,900	3,270	--	XX
Total	316,000	62,100	68,000	40,300	486,000

W Withheld to avoid disclosing company proprietary data. XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 12
ZINC CONTAINED IN PIGMENTS AND COMPOUNDS PRODUCED AND SHIPPED IN THE UNITED STATES[1,2]

(Metric tons)

	2004		2005	
	Production	Shipments	Production	Shipments
Zinc oxide	29,500	28,400	29,500	29,500
Zinc sulfate	24,300	24,200	24,000	24,000

[1]Excludes leaded zinc oxide, lithopone, and zinc chloride.

[2]Data are rounded to no more than three significant digits.

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TABLE 13
REPORTED SHIPMENTS OF ZINC CONTAINED IN ZINC OXIDE, BY INDUSTRY[1, 2]

(Metric tons)

	2004	2005
Ceramics	383	418
Chemicals	5,000	5,320
Paints	1,820	1,840
Rubber	20,300	21,000
Other[3]	895	975
Total	28,400	29,500

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]In addition, zinc contained in zinc oxide was imported as follows: 2004—103,089 and 2005—109,247; distribution cannot be distinguished by industry.

[3]Includes agriculture and photocopying.

TABLE 14
U.S. EXPORTS OF ZINC ORES AND CONCENTRATES, BY COUNTRY[1]

	2004		2005	
	Quantity (metric tons, zinc content)	Value (thousands)	Quantity (metric tons, zinc content)	Value (thousands)
Australia	37,300	$21,600	48,800	$31,400
Belgium	74,000	36,100	35,900	23,600
Brazil	287	167	--	--
Bulgaria	32,400	18,800	21,300	13,700
Canada	152,000	119,000	178,000	142,000
China	865	187	19	12
Finland	33,400	19,400	33,500	21,600
Gambia, The	12,200	7,080	15,200	9,800
Germany	20,300	11,800	17,700	11,400
Italy	8	17	38,400	24,700
Japan	111,000	40,000	136,000	48,600
Korea, Republic of	184,000	90,000	177,000	97,900
Netherlands	--	--	--	--
Spain	86,900	47,900	84,000	51,800
Other	217	378	921	685
Total	745,000	413,000	786,000	477,000

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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TABLE 15
U.S. EXPORTS OF ZINC COMPOUNDS[1]

	2004		2005	
	Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)
Zinc chloride	1,870	$2,200	1,860	$2,310
Zinc compounds, n.s.p.f.[2]	7,840	14,300	10,400	19,400
Zinc oxide	14,400	19,800	14,600	23,600
Zinc sulfate	3,060	1,860	2,820	1,870

[1]Data are rounded to no more than three significant digits.
[2]Not specifically provided for.

Source: U.S. Census Bureau.

TABLE 16
U.S. IMPORTS FOR CONSUMPTION OF ZINC COMPOUNDS[1]

	2004		2005	
	Quantity (metric tons, gross weight)	Value (thousands)	Quantity (metric tons, gross weight)	Value (thousands)
Lithopone	3,950	$2,600	6,390	$4,930
Zinc chloride	705	863	723	1,250
Zinc compounds, n.s.p.f.[2]	16	29	11	28
Zinc hydrosulfite	102	300	177	309
Zinc oxide	103,000	89,000	109,000	127,000
Zinc sulfate	29,100	14,000	31,100	16,600

[1]Data are rounded to no more than three significant digits.
[2]Not specifically provided for.

Source: U.S. Census Bureau.

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TABLE 17

ZINC: WORLD MINE PRODUCTION (ZINC CONTENT OF CONCENTRATE AND DIRECT SHIPPING ORE UNLESS NOTED), BY COUNTRY[1, 2]

(Metric tons, zinc content of concentrate and direct shipping ore, unless otherwise specified)

Country	2001	2002	2003	2004	2005[e]
Algeria	10,693	8,576	2,796 [r]	231 [r]	4,463 [3]
Argentina	39,703	37,325	29,839 [r]	27,220 [r]	28,000
Australia	1,519,000	1,144,000 [r]	1,447,000 [r]	1,298,000 [r]	1,329,000 [3]
Bolivia	145,306	141,558	144,985	145,906 [r]	158,582 [3]
Bosnia and Herzegovina[e]	300	300	300	300	300
Brazil	111,432	136,339	152,822 [r]	158,962 [r]	160,000
Bulgaria[e]	12,100	14,900	12,000	11,000	11,000
Burma	467	138 [r, 4]	127 [r, 4]	196 [r, 4]	200
Canada	1,012,048	923,930 [r]	757,307 [r]	735,698 [r]	755,000
Chile	32,762	36,161	33,051	27,635 [r]	28,000
China	1,700,000	1,550,000	2,030,000	2,390,000 [r]	2,450,000
Congo (Kinshasa)	1,014	-- [r]	-- [r]	--	--
Ecuador[e]	100	100	100	-- [r]	--
Finland	36,253	35,000 [r]	39,000 [r]	37,000 [r]	41,000 [3]
Georgia[e]	200	400	400	400	400
Greece	31,700	33,000	3,000	--	--
Honduras	48,485	46,339	43,766 [r]	41,413 [r]	42,698 [3]
India[e]	146,000	234,300 [r]	306,400 [r]	341,000	446,000 [3]
Iran[e]	120,000	120,000	110,000 [r]	121,000 [r]	125,000
Ireland	225,135	252,700	419,000	438,000	429,000
Japan	44,519	42,851	44,574	47,781 [r]	41,452 [3]
Kazakhstan	344,300	390,000	395,000	360,000	400,000
Korea, North[e]	60,000	60,000	60,000	62,000 [r]	67,000
Korea, Republic of	5,129	99	-- [e]	--	--
Macedonia	6,300	10,000 [r]	4,000 [r]	--	--
Mexico	428,828	446,104	413,991 [r]	426,330 [r]	470,000
Morocco	89,339	90,487 [r]	69,200 [r]	74,600 [r]	75,000
Namibia	37,622	42,685	60,500 [r, 5]	66,028 [r, 4]	70,000
Peru	1,056,629	1,221,830	1,372,790	1,209,006	1,201,671 [3]
Poland	152,700	152,200	153,900 [r]	140,300 [r]	117,200 [3]
Romania	29,786	21,200	22,081 [r]	18,604 [r]	25,000
Russia[e]	124,000	130,000 [3]	159,000	179,000	180,000
Saudi Arabia[e]	3,300 [3]	3,000	3,000	1,500	1,500
Serbia and Montenegro	5,988	6,900	--	--	--
South Africa	61,560 [r]	64,580 [r]	41,400 [r]	32,310 [r]	32,112 [p]
Spain	164,900	69,900	15,000	--	--
Sweden	156,334	148,600	188,000 [r]	199,000 [r]	216,000 [3]
Thailand	15,300	31,000 [r]	43,400 [r]	29,900 [r]	42,570 [3]
Tunisia	37,900 [e]	35,692	38,000 [e]	31,000	19,000
Turkey	37,000	43,000	40,000	39,000	48,000 [3]
United States	842,114	780,026	767,597	738,876	748,000 [3]
Vietnam[e]	32,000 [r]	42,000 [r]	45,000 [r]	30,000 [r]	32,000
Total	8,928,246 [r]	8,547,220 [r]	9,468,326 [r]	9,459,196 [r]	9,795,148

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through July 1, 2006.

[3]Reported figure.

[4]Data are for fiscal year ending March 31 of the following year.

[5]Anglo American plc's Skorpion solvent extraction-electrowinning plant started production in 2003.

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TABLE 18

ZINC: WORLD SMELTER PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Algeria, primary and secondary	26,000 [r]	33,900 [r]	34,900 [r]	36,800 [r]	32,000 [4]
Argentina:					
Primary	39,727	38,699	39,221 [r]	35,300 [r]	35,000
Secondary	3,180	3,098	3,139 [r]	3,000 [r]	3,000
Total	42,907	41,797	42,360 [r]	38,300 [r]	38,000
Australia:					
Primary[5]	554,000	567,000	553,000	473,000	503,300 [4]
Secondary[e]	4,500	4,500	4,500	4,500	4,500
Total	558,500	571,500	557,500	477,500	507,800 [4]
Belgium, primary and secondary[e]	259,300 [4]	260,000	244,000	263,000	257,000
Brazil:					
Primary	193,061	247,692 [r]	257,530 [r]	265,987 [r]	270,000
Secondary[e]	7,000	7,000	7,000	7,000	7,000
Total	200,061	254,692 [r]	264,530 [r]	272,987 [r]	277,000
Bulgaria, primary and secondary	88,600	83,000	86,800	102,000 [r]	95,000 [4]
Canada, primary	661,172	793,410 [r]	761,199	804,219 [r]	805,000
China, primary and secondary[e]	2,040,000	2,100,000	2,320,000	2,720,000 [r]	2,800,000
Czech Republic, secondary[e]	250	200	250	250	250
Finland, primary	247,179	235,300	265,900	284,500 [r]	292,000 [4]
France, primary and secondary[e]	347,000	350,000	253,000	260,000	268,000
Germany, primary and secondary	358,341 [r]	378,561 [r]	388,131 [r]	382,020 [r]	380,000 [4]
India:					
Primary	207,000 [e]	231,400	253,900	238,400	270,000 [4]
Secondary[e]	25,000	24,000	24,000	24,000	23,000
Total	232,000	255,400	277,900	262,400	293,000 [4]
Iran	73,000 [e]	82,571 [r]	78,428 [r]	109,400 [r]	140,000 [4]
Italy, primary and secondary	177,800	176,000	123,000 [e]	130,000	121,000
Japan:					
Primary	541,277	547,183	532,704	534,830	536,768 [4]
Secondary	142,777	126,723	153,411	132,417	138,453 [4]
Total	684,054	673,906	686,115	667,247	675,221 [4]
Kazakhstan, primary and secondary	277,100	286,300	279,000	316,500	356,907 [4]
Korea, North, primary and secondary[e]	65,000 [r]	65,000 [r]	65,000 [r]	67,000 [r]	72,000
Korea, Republic of, primary	503,315 [r]	605,990 [r]	644,218 [r]	668,666 [r]	644,828 [4]
Laos	28,745	1,345	3,069	2,000	87,379
Macedonia, primary and secondary[e]	52,000	56,000	28,000	25,000 [r]	25,000
Mexico, primary	303,810	302,122	320,364	325,220 [r]	360,000
Mongolia	--	--	--	--	22,800 [4]
Namibia[6]	--	35	47,436	119,200	132,800 [4]
Netherlands, primary[e, 7]	204,800 [4]	203,000	223,000	225,000	228,000
Norway, primary	129,300 [r]	145,000	142,000	139,000 [r]	148,000 [4]
Peru, primary	204,646	172,688	202,076	195,692	163,603 [4]
Poland, primary and secondary	174,700	158,900	153,300	153,000	155,000
Portugal, secondary[e]	3,600	3,600	3,500	1,500	3,000
Romania, primary and secondary	47,200	51,600	52,000	55,000 [r]	57,000 [4]
Russia, primary and secondary[e]	237,000	244,000	253,000	240,000	220,000
Serbia and Montenegro, primary and secondary	13,467	1,478	62	100	100
Slovakia, secondary[e]	1,000	1,000	1,000	1,000	1,000
South Africa, primary	109,000	111,000 [r]	113,000 [r]	104,000	102,000 [4]

See footnotes at end of table.

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TABLE 18—Continued

ZINC: WORLD SMELTER PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003	2004	2005[e]
Spain, primary and secondary	418,000	488,000	519,000	525,000	546,000
Thailand, primary	104,797 [r]	105,148 [r]	113,686 [r]	115,100 [r]	101,186 [4]
United Kingdom, primary and secondary	100,000 [r]	99,600 [r]	16,600 [r]	--	--
United States:					
Primary	203,000	182,000	187,000	189,000	191,000 [4]
Secondary	108,000	113,000	116,000	117,000	118,000 [4]
Uzbekistan, primary[e]	35,000	30,000	30,000	30,000	30,000
Grand total	9,320,000 [r]	9,720,000 [r]	9,900,000 [r]	10,400,000 [r]	10,700,000
Of which:					
Primary	4,240,000 [r]	4,520,000 [r]	4,640,000 [r]	4,630,000 [r]	4,680,000
Secondary	295,000	283,000	313,000 [r]	290,000	298,000
Undifferentiated	4,780,000 [r]	4,920,000 [r]	4,940,000 [r]	5,510,000 [r]	5,770,000

[e]Estimated. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Wherever possible, detailed information on raw material source of output (primary--directly from ores, and secondary--from scrap) has been provided. In cases where raw material source is unreported and insufficient data are available to estimate the distribution of the total, that total has been left undifferentiated (primary and secondary). To the extent possible, this table reflects metal production at the first measurable stage of metal output. Table includes data available through July 1, 2006.

[3]In addition to the countries listed, Israel also produces small amounts of secondary zinc, but available information is inadequate to make reliable estimates of output levels.

[4]Reported figure.

[5]Excludes zinc dust.

[6]Special high-grade electrowon cathodes from Anglo American plc's Skorpian solvent extraction-electrowinning plant.

[7]Sales.

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Zirconium and Hafnium

By Joseph Gambogi

Domestic survey data and tables were prepared by Mahbood Mahdavi, statistical assistant, and the world production table was prepared by Linder Roberts, international data coordinator.

In 2005, global demand for zirconium minerals continued to exceed supply. The cause of the shortage was the result of several factors, including increased demand, the closure of some zircon-producing mines, and reduced zircon grades at a few mines. China's tremendous economic growth significantly influenced the price and availability of zirconium minerals. Although domestic list prices of standard-grade zircon decreased, domestic premium-grade zircon prices reflected the increase in global demand.

The principal economic source of zirconium is the zirconium silicate mineral zircon ($ZrSiO_4$). A relatively small quantity of zirconium is derived from the mineral baddeleyite, a natural form of zirconium oxide or zirconia (ZrO_2). In 2005, zircon, the principal ore material, was mined at many locations worldwide, primarily Australia, South Africa, and the United States. Baddeleyite was produced from a single source at Kovdor, Russia.

Zircon is the primary source of hafnium. Zirconium and hafnium are contained in zircon at a ratio of about 50 to 1. Zircon is a coproduct or byproduct of the mining and processing of heavy-mineral sands for the titanium minerals ilmenite and rutile or for tin minerals. The major end uses of zircon, in descending order of quantity, are refractories, foundry sands (including investment casting), and ceramic opacification. Zircon is also marketed as a natural gemstone and is processed to produce cubic zirconia, a diamond and colored gemstone simulant. Zirconium metal is used in nuclear fuel cladding, chemical piping, pumps, and valves in corrosive environments, heat exchangers, and various specialty alloys.

The principal uses of hafnium are in nuclear control rods, nickel-base superalloys, nozzles for plasma arc metal cutting, and high-temperature ceramics.

World production of zirconium mineral concentrates in 2005, excluding U.S. production, was estimated to be about the same level as it was in 2004. Domestic production of zircon increased moderately in 2005 compared with production in 2004. In 2005, production of milled zircon and zirconium oxide increased when compared with that of 2004. The United States was a net exporter of zirconium ore and concentrates. U.S. imports of zirconium ore and concentrates in 2005 increased by 8% compared with those of 2004, and domestic exports of zirconium ore and concentrate increased by 47%.

With the exception of prices and referenced data, all survey data in this report have been rounded to no more than three significant digits. Totals and percentages were calculated from unrounded numbers.

Production

Data for zirconium and hafnium manufactured materials are developed by the U.S. Geological Survey from a voluntary survey of domestic operations. Of the 43 operations surveyed, 31 did not respond. Data for nonrespondents were estimated on the basis of prior-year levels.

Data for zircon concentrates are developed by a second voluntary survey of domestic mining operations. Of the two domestic zircon producers, which had four mining and processing operations, 100% responded. Data on domestic production and consumption of zircon concentrates were withheld to avoid disclosing company proprietary data.

Domestic production of milled zircon was unchanged and of zirconium oxide decreased by 6% from their 2004 levels (table 1). Domestic production of zircon concentrate in 2005 decreased by about 6% compared with that of 2004.

Zircon is normally produced as a byproduct of the mining and processing of heavy-mineral sands containing the titanium minerals ilmenite and rutile. In 2005, U.S. producers of zircon were DuPont Titanium Technologies [a subsidiary of E.I. du Pont de Nemours & Co. (DuPont)] and Iluka Resources, Inc. (a subsidiary of Australian company Iluka Resources Ltd.). DuPont produced zircon from its heavy-mineral sands operation near Starke, FL. Iluka produced zircon from its heavy-mineral sand operations at Green Cove Springs, FL, Lulaton, GA, and Stony Creek, VA.

In December, Iluka announced plans for a staged closure of its Florida and Georgia mining operations beginning in 2006. The closure was attributed in part to financial losses from mining small, thin, and disparate low-grade deposits and rising operating costs. Although the Florida operations had been producing heavy minerals since 1972, the Georgia operations were commissioned in 2004.

U.S. producers of zirconium and hafnium metal were Wah Chang (an Allegheny Technologies, Inc. company), Albany, OR, and Western Zirconium (a subsidiary of Westinghouse Electric Co.), Ogden, UT. Primary zirconium chemicals, those produced directly from zircon, were produced by Wah Chang and Magnesium Elektron Inc., Flemington, NJ. Secondary zirconium chemicals, produced from intermediate zirconium chemicals, were produced by about 10 companies. Zirconia was produced from zircon sand at plants in several States.

Consumption

Approximately 95% of the consumption of zirconium is as zircon, zirconium oxide, or other zirconium chemicals. The remainder is consumed as zirconium metal and zirconium-containing alloys.

Zircon, used for facings on foundry molds, increases resistance to metal penetration and gives a uniform finish to castings. Milled or ground zircon is used in refractory paints for coating the surfaces of molds. In the form of refractory bricks

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and blocks, zircon is used in furnaces and hearths for containing molten metals. Glass tank furnaces use fused-cast and bonded alumina-zirconia-silica-base refractories. Baddeleyite is used principally in the manufacture of alumina-zirconia abrasive and in ceramic colors and refractories.

Stabilized zirconium oxide exhibits high light reflectivity and good thermal stability and is primarily used as an opacifier and pigment in glazes and colors for pottery and other ceramic products. Yttria-stabilized zirconia (YSZ) is used in the manufacture of oxygen sensors that control combustion in furnaces and automobile engines. YSZ is also used in the manufacture of a diverse array of products, including high-temperature, high-strength structural ceramics, heat- and break-resistant shirt buttons, golf shoe spikes, golf putters, fiber optic connector components, refractory coatings for jet engines, and cubic zirconia, a gemstone simulant for diamonds and colored gemstones. YSZ is increasingly used in dental applications as inlays, crowns, and bridges as it has two to three times the fracture resistance and 1.4 times the strength of similar alumina products.

Ammonium- and potassium-zirconium carbonates are used as paper and board coatings or insolubilizers for high-quality print performance. Zirconium chemicals are also used in inks to promote adhesion to metals and plastics and as crosslinkers in polymers and printing inks.

Because of its low thermal neutron absorption cross section, hafnium-free zirconium metal is used as cladding for nuclear fuel rods. Commercial-grade zirconium, unlike nuclear grade, contains hafnium and is used in the chemical process industries because of its excellent corrosion resistance.

Hafnium is used in nuclear control rods because of its high thermal neutron absorption cross section. However, the leading end use for hafnium metal is as an alloy addition in superalloys.

Prices

In 2005, increased demand for zircon concentrates resulted in increased prices. The average value of imported ore and concentrates increased to $674 per metric ton in 2005 from $477 per ton in 2004. The average value of zircon ore and concentrates exports increased to $734 per ton in 2005 from $661 per ton in 2004.

Published prices for bulk grades of zircon, free on board, increased for ceramic, refractory, and foundry grades (Industrial Minerals, 2005). Australian zircon prices increased to $620 to $700 per ton at yearend 2005 from $450 to $550 per ton at yearend 2004. U.S. prices for premium-grade zircon concentrate increased to $562 per ton in 2005 from a revised $462 per ton in 2004 (table 2). In contrast to all other zirconium concentrate prices, the published price for standard grade zircon decreased to $415 per ton in 2005 from $455 per ton in 2004.

Foreign Trade

The United States was a net exporter of zirconium ore and concentrates in 2005. U.S. exports of zirconium ore and concentrates were 101,000 metric tons (t), a 47% increase from those of 2004 (table 3). The United States was a net exporter of zirconium and hafnium metal in 2005. U.S. exports of zirconium metal were 1,970 t, a 16% increase in quantity from the 2004 level. U.S. zirconium metal exports and imports are classified under the Harmonized Tariff Schedule of the United States (HTS) with tariff numbers falling under the 8109 prefix. In 2005, the majority (84%) of zirconium metal was exported in wrought products.

U.S. imports of zirconium ore and concentrates were 38,200 t, an increase of 8% from the 35,200 t imported in 2004 (table 4). Australia and South Africa supplied 93% of the imports of ores and concentrates. Imports of unwrought zirconium were 269 t in 2005, and the leading sources, in descending order of quantity, were France (86%), Germany (10%), and Japan (4%). Imports of zirconium waste and scrap were 14 t in 2005, and the leading sources, in descending order of quantity, were Japan (57%), Germany (29%), and Canada (14%). Domestic imports of ferrozirconium alloys were 306 t in 2005, a 85% increase from the 165 t imported in 2004. In 2005, ferrozirconium imports originated primarily from Brazil (99%). U.S. imports of hafnium were 4 t in 2005, unchanged compared with those of 2004.

World Industry Structure

Excluding U.S. production, world production of zirconium mineral concentrates in 2005 was estimated to be 881,000 t, essentially the same as that of the revised 2004 data (table 5). An Australian publication estimated that world zirconium mineral production increased to 1.18 million metric tons (Mt) in 2005 from 1.15 Mt in 2004 (Mineral Sands Report, 2006).

Australia and South Africa supplied about 69% of all production outside the United States. World reserves of zircon are estimated to be 38 Mt of zirconium oxide. During 2005, because of increased demand for zircon, the heavy-mineral sands industry continued to be active in the exploration and development of mineral deposits on a global basis, particularly in Australia, Kenya, Mozambique, South Africa, and the United States. Major zircon producers, in order of decreasing production capacity, were Iluka (Australia/United States), Richards Bay Minerals (RBM) (South Africa), Namakwa Sands (Pty.) Ltd. (South Africa), Tiwest Joint Venture (Australia), DuPont (United States), Ticor South Africa (Ticor SA) (South Africa), Consolidated Rutile Ltd. (CRL) (Australia), Vilnohirsk State Mining & Metallurgical (Ukraine), Bemax Resources NL (Australia), and Millenium Inorgânica Chemicals do Brasil S/A (Brazil).

Global fused zirconia production was estimated to be in range of 45,000 to 55,000 metric tons per year (t/yr). Capacity was estimated to be 65,000 t/yr. China, India, and the Republic of Korea were identified as major growth markets for stabilized zirconia (Industrial Minerals, 2006a).

World Review

Australia.—Astron Ltd. made plans to proceed with the development of its Donald Heavy Mineral Sands Project in Victoria. Production was scheduled to begin in 2007. Initial mine capacity was expected to be up to 500,000 t/yr of heavy minerals, including 86,000 t/yr of zircon concentrate (Astron Ltd., 2006§)

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Australian Zircon NL completed a drilling program at its Mindarie mineral sands project in the western Murray Basin. The deposit was estimated to have 1.6 Mt of measured heavy-mineral resources. Australian Zircon expected to commence production near yearend 2006 (Australian Zircon NL, 2005§[1]).

In December, Bemax began mining at the Pooncarie mineral sands project in the Murray Basin. The company planned to begin trucking heavy-mineral concentrate from the Ginko mine to the Broken Hill mineral separation plant in 2006. The Ginkgo mine was reported to contain 5.8 Mt of heavy minerals, with a mine life of more than 25 years. During 2005, Bemax upgraded its Bunbury mineral separation plant to allow it to simultaneously process feedstock from its Western Australia (Cable Sands) and Murray Basin operations as well as toll feedstock (Bemax Resource NL, 2006§).

Iluka continued work on the development of heavy-mineral deposits in the Murray and Eucla Basins. In 2004, Iluka started stockpiling ore for its Douglas project in the Murray Basin, Victoria. By yearend 2005, Iluka had completed mine construction and was preparing to commission the wet concentration plant for the Douglas project. A mineral separation plant located near Hamilton was expected to be completed in mid-2006. In the first year of operation, production was expected to be 180,000 t of rutile and zircon. In the northern Murray Basin, Iluka was in the prefeasibility phase in the development of its Euston and Ouyen deposits. In the Eucla Basin, Iluka continued the delineation of its Ambrosia, Jacinth, and Tripitaka deposits (Iluka Resources Ltd., 2006§).

Olympia Resources Ltd. announced the completion of a bankable feasibility study for its Keysbrook mineral sands project, south of Perth. Keysbrook was expected to have a mine life of 11 years (Olympia Resources Ltd., 2005§). Olympia has identified a reserve of 1.2 Mt of heavy minerals at Keysbrook with startup scheduled for 2007 (Olympia Resources Ltd., 2006§).

Canada.—Titanium Corp., Inc. continued efforts to commercialize the recovery of heavy-minerals from the oil sands tailings of Syncrude Canada Ltd. in Alberta. In 2005, Titanium Corp. used its pilot facility to optimize the recovery of heavy minerals and improve product quality. At yearend, the company began a drill core analysis program to quantify the heavy-mineral resource in the oil sands project (Titanium Corp., Inc., 2006§).

China.—Astron Ltd. announced plans to increase production capacity of its range of monoclinic zirconia at its Bayuchuan operation to 16,000 t/yr from 13,000 t/yr though process improvements. In addition, two new 3,000-t/yr furnaces dedicated to stabilized zirconia were expected to begin production by yearend 2006. The new furnaces were expected to raise the operation's stabilized zirconia capacity to 7,000 t/yr (Industrial Minerals, 2005).

Gambia, The.—Carnegie Corp. Ltd. completed a trial dredge program at the Sanyang heavy-mineral sands deposit. In 2004, the company completed an environmental impact assessment and received approval for its environmental management plan. At yearend 2005, the company was waiting for the approval of the mining lease (Carnegie Corp. Ltd., 2005§). The project is a joint venture with Aston Ltd. and could yield 20,000 t/yr of zircon (Industrial Minerals, 2005).

Kenya.—Tiomin Resources Inc. continued the development of its Kwale heavy-mineral sands project located 40 kilometers south of Mombasa. In 2005, Tiomin was engaged in project financing and announced it had secured sales agreements with two Chinese firms for future output from the mine. The construction phase of the project was expected to begin in 2006. When completed, the project was expected to produce about 330,000 t/yr of ilmenite, 75,000 t/yr of rutile, and 40,000 t/yr of zircon (Tiomin Resources Inc., 2005§).

Madagascar.—In August, Rio Tinto plc announced the approval to fund the development of the Fort-Dauphin mineral sands project. The project was being developed by QIT Madagascar Minerals (QMM) [a Malagasy subsidiary of Rio Tinto (80%) and the Government of Madagascar (20%)]. Part of the project requires the construction of a deep-sea port funded by public and private interests. Mine production was expected to reach 750,000 t/yr of ilmenite and 25,000 t/yr of zircon. Mining startup was scheduled for 2008. The mine life could extend for 40 years (Rio Tinto plc, 2005§).

Mozambique.—At yearend, Kenmare Resources plc. was midway through the construction phase of its Moma heavy-mineral sands project. Commissioning of the wet and dry separation plants was expected by yearend 2006. Production capacity from the mine was expected to reach 701,000 t/yr of ilmenite, 17,000 t/yr of rutile, and 60,000 t/yr of zircon (Kenmare Resources plc., 2006§).

In March, BHP Billiton Ltd. acquired Australian-based WMC Resources Ltd. The acquisition brought BHP's interest in the Corridor Sands project in southern Mozambique to 90%. In 2005, BHP was reviewing and updating previously conducted feasibility studies prior to making a decision whether to move into the feasibility phase during 2006. In 2004, BHP also held a 100% interest in the TiGen heavy-minerals project in Moebase. A prefeasibility study was completed for the TiGen project, and market studies were being examined to determine when the project should move into the feasibility phase (BHP Billiton plc, 2005§).

Russia.—In 2005, production of baddeleyite at Kovdorsky GOK reached 6,700 t, a record level. The company had completed a program to upgrade and modernize the operation. Baddeleyite shipments in 2004 were 6,470 t (Industrial Minerals, 2006b).

Senegal.—Mineral Deposits Ltd. (MDL) made plans to relocate its Australian-based dredge and wet concentration plant to its Grande Côte heavy-mineral sands project. The project is located within the Senegal-Mauritania Basin along the northwestern coast of Senegal, south of St. Louis. MDL hoped to commence production in 2007 with a mine capacity of about 75,000 t/yr of zircon and 14,000 t/yr of leucoxene (Mineral Deposits Ltd., 2005§).

South Africa.—Australian-based Kumba Resources Ltd. acquired the outstanding 40% interest in the heavy-mineral producer Ticor SA. In 2005, Ticor SA's heavy minerals operation near Empangeni, KwaZulu-Natal Province, produced 47,000 t of zircon, a 4% decrease compared with output in 2004 (Kumba Resources Ltd., 2006§).

[1]References that include a section mark (§) are found in the Internet References Cited section.

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In parallel with the production of titanium heavy minerals, zircon production at RBM in KwaZulu-Natal Province, increased significantly. In 2005, zircon production increased by 16% compared with that of 2004. RBM is the trading name for two companies, Tisand (Pty) Ltd. and Richards Bay Iron and Titanium (Pty) Ltd. Ownership interest in RBM is shared equally between Rio Tinto plc and BHP Billiton plc. (Rio Tinto plc, 2006§).

Namakwa Sands improved recovery and raised rutile and zircon production at the Namakwa Sands heavy-mineral sands operation near Brand se Baai. In 2005, Namakwa Sands began an expansion project to increase rutile output by 26% and zircon production by approximately 20%. Namakwa Sands is wholly owned by Anglo American plc (Anglo American plc, 2006§).

Outlook

The global shortage of zirconium materials was expected to continue in 2006. Growth in demand of 3% to 5% per year through the next decade was expected, and new deposits were expected to come online to improve the supply. Increased demand relative to the available supply will contribute to continued pressure for price increases in the short term, especially in the spot market.

Beyond the next few years, supply and demand for zircon are expected to be in closer balance as new deposits and plant expansions come online. Expansions in supply are expected in Australia, Madagascar, Mozambique, and South Africa.

A new trend in the heavy-mineral sands industry appears to be the sale of semiprocessed concentrates. In 2005, several projects were underway that did not include an integrated facility for mineral separation.

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TABLE 1
SALIENT U.S. ZIRCONIUM STATISTICS[1]

(Metric tons)

	2001	2002	2003	2004	2005
Zircon:					
Production:					
Concentrates	W	W	W	W	W
Milled zircon (ZrO_2 content)	59,100	37,000	35,200	31,400	31,400
Exports[r]	66,900	47,100	70,600	68,800	101,000
Imports for consumption[r, 2]	60,600	35,300	37,400	35,200	38,200
Consumption, apparent[2, 3]	W	W	W	W	W
Stocks, December 31 (ZrO2 content), dealers and consumers[4]	37,700	21,600	27,900	16,700	16,100
Zirconium oxide:					
Production (ZrO_2 content)[5]	21,500	17,600	20,400	21,300	19,900
Exports[6]	2,400	1,950	1,520	1,600	2,260
Imports for consumption[6]	2,950	2,900	2,350	3,960	3,160
Consumption, apparent[3]	24,600	18,300	20,700	23,700	21,000
Stocks, December 31, producers[5]	2,730	2,490	2,030	2,070	2,210
Zirconium; unwrought powder, waste and scrap, other:					
Exports	1,380	1,640	1,700	1,700	1,970
Imports	659	556	542	796	1,020
Ferrozirconium:					
Exports	251	868	1,930	913	65
Imports	240	167	154	165	306
Hafnium; unwrought powder, waste and scrap, other, imports	5	5	5	4	4

[r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Data are rounded to no more than three significant digits.
[2]Includes insignificant amounts of baddeleyite.
[3]Defined as production plus imports for consumption minus exports plus or minus government shipments plus or minus stock changes.
[4]Excludes foundries.
[5]Excludes intermediate oxides associated with metal production.
[6]Includes germanium oxides and zirconium dioxides.

TABLE 2
PUBLISHED YEAREND PRICES OF ZIRCONIUM AND HAFNIUM MATERIALS

Specification of material		2004	2005
Zircon:			
Domestic, standard-grade, bulk[1]	dollars per short ton	455.00	415.00
Domestic, premium-grade zircon[1]	do.	462.00 [r]	562.00
Imported sand, ceramic-grade, free on board, bulk[2]	dollars per metric ton	460.00-550.00	620.00-700.00
Imported sand, refractory-grade, free on board[2]	do.	450.00-550.00	620.00-700.00
Imported sand, foundry sand-grade, free on board, bulk[2]	do.	450.00-550.00	620.00-700.00
Baddeleyite, contract price, cost, insurance, and freight main European port:[3]			
Refractories/abrasive grade	dollars per metric ton	2,000-2,400	2,200-2,600
Ceramic grade (98% zirconium oxide and hafnium oxide)	do.	2,600-3,000	2,800-3,200
Zirconium oxide:[4]			
100 kilograms:[5]			
Calcia stabilized zirconia	dollars per kilogram	20.70	20.70
Magnesia stabilized zirconia	do.	21.00	21.00
Yttria (3 mole%) stabilized zirconia	do.	22.40	22.40
Yttria (8 mole%) fully stabilized zirconia	do.	24.10	24.10
1,000 kilograms:[5]			
Calcia stabilized zirconia	dollars per kilogram	18.10	18.10
Magnesia stabilized zirconia	do.	19.40	19.40
Yttria (3 mole%) stabilized zirconia	do.	18.80	18.80
Yttria (8 mole%) fully stabilized zirconia	do.	20.10	20.10

[r]Revised.
[1]Domestic average price.
[2]Source: Industrial Minerals, no. 446, December 2004, p. 73; no. 459, December 2005, p. 71.
[3]Source: Industrial Minerals, no. 446, December 2004, p. 72; no. 459, December 2005, p. 70.
[4]Source: Stanford Materials Corp., [undated], Zirconium (Zr), accessed July 19, 2006, at URL http://www.stanfordmaterials.com/zr.html.
[5]Prices are for bulk quantities; nominal, free on board California.

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TABLE 3
U.S. EXPORTS OF ZIRCONIUM, BY CLASS AND COUNTRY[1]

Class and country	HTS[2]	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Ore and concentrates:	2615.10.0000				
Argentina		563	$495	1,260	$1,510
Belgium		2,540	1,290	2,330	1,690
Brazil		1,190	1,060	2,380	2,220
Canada		7,750	4,320	12,500	7,390
China		1,380	1,930	873	1,720
Colombia		2,470	2,320	2,600	2,790
Dominican Republic		207	191	85	92
Ecuador		202	184	113	126
France		560	437	1,380	1,010
Georgia		11	10	--	--
Germany		3,850	2,270	622	563
Guyana		--	--	1	5
Hong Kong		6	3	1	4
India		294	391	477	907
Indonesia		14	19	18	27
Ireland		36	52	34	52
Israel		256	330	159	205
Italy		17,700	7,790	25,600	16,600
Japan		2,580	2,800	2,660	3,570
Korea, Republic of		1,480	2,500	1,280	2,970
Malaysia		--	--	73	36
Mexico		11,800	6,620	19,400	11,500
Netherlands		10,100	4,280	23,000	13,700
Pakistan		428	351	68	68
Portugal		9	4	--	--
South Africa		10	21	--	--
Spain		--	--	368	282
Sweden		69	51	69	61
Taiwan		30	115	27	24
Turkey		--	--	1,000	554
United Kingdom		2,880	5,220	2,180	3,970
Venezuela		394	349	312	392
Vietnam		126	109	--	--
Other		7	6	32	24
Total		68,800	45,500	101,000	74,000
Ferrozirconium:	7202.99.1000				
Canada		7	13	6	14
China		18	64	--	--
Germany		8	8	9	9
Japan		--	--	27	27
Korea, Republic of		(3)	7	--	--
Mexico		881	1,210	24	51
Total		913	1,310	65	100
Unwrought zirconium, powder:	8109.20.0000				
Brazil		(3)	10	4	29
Canada		2	65	3	132
Costa Rica		--	--	4	86
France		11	357	4	235
Germany		2	89	6	188
Hungary		4	118	12	407
Italy		1	34	(3)	28
Japan		23	565	24	649
Korea, Republic of		1	13	8	72
Mexico		2	52	3	124
Nicaragua		--	--	3	62
Norway		1	33	4	158
United Kingdom		90	1,250	97	1,390
Other		(3)	14	1	60
Total		138	2,600	175	3,620

See footnotes at end of table.

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TABLE 3—Continued
U.S. EXPORTS OF ZIRCONIUM, BY CLASS AND COUNTRY[1]

Class and country	HTS[2]	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Zirconium waste and scrap:	8109.30.0000				
Austria		--	--	19	277
Belgium		--	--	19	83
Brazil		--	--	2	30
Canada		21	937	28	1,410
China		4	41	--	--
France		7	81	10	106
Germany		--	--	23	249
Israel		(3)	4	--	--
Italy		14	117	5	49
Japan		48	537	24	422
Korea, Republic of		(3)	3	--	--
Philippines		--	--	2	36
Singapore		(3)	12	--	--
Taiwan		(3)	6	--	--
United Kingdom		2	54	16	419
Total		96	1,790	146	3,080
Other zirconium:	8109.90.0000				
Argentina		32	1,870	39	1,830
Belgium		4	435	2	330
Brazil		6	806	9	175
Canada		379	19,400	268	17,500
China		175	11,100	164	11,700
Finland		1	124	5	291
France		34	2,440	80	4,450
Germany		62	3,830	36	2,340
Italy		4	255	15	1,050
Japan		238	14,800	683	15,000
Korea, Republic of		150	16,000	179	18,400
Malaysia		4	48	(3)	13
Mexico		28	782	21	693
Spain		54	8,040	50	7,240
Sweden		7	637	7	841
Taiwan		29	2,030	15	243
United Kingdom		99	6,040	52	4,490
Other		162 r	1,950	25	711
Total		1,470	90,600	1,650	87,200

rRevised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States.
[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 4
U.S. IMPORTS FOR CONSUMPTION OF ZIRCONIUM AND HAFNIUM, BY CLASS AND COUNTRY[1]

Class and country	HTS[2]	2004 Quantity (metric tons)	2004 Value (thousands)	2005 Quantity (metric tons)	2005 Value (thousands)
Zirconium ore and concentrates:	2615.10.0000				
Australia		23,600	$9,450	20,500	$11,200
Canada		1,310	718	161	118
China		1,050	1,770	2,000	4,240
Germany		28	45	157	151
India		12	67	32	122
Italy		39	24	--	--
Japan		3	21	5	22
Russia		422	985	266	675
South Africa		8,700	3,690	15,000	9,160
United Kingdom		--	--	3	18
Other		20	16	5	17
Total		35,200	16,800	38,200	25,700
Ferrozirconium:	7202.99.1000				
Brazil		124	234	304	662
China		(3)	3	(3)	4
Norway		37	34	--	--
United Kingdom		4	47	1	9
Total		165	318	306	675
Unwrought zirconium, powder:	8109.20.0000				
China		41	388	--	--
France		5	185	230	4,300
Germany		19	1,650	28	1,680
Other		9	99	11	24
Total		75 r	2,320	269	6,000
Zirconium waste and scrap:	8109.30.0000				
Japan		14	64	8	70
Other		1	6	6	94
Total		15	70	14	164
Other zirconium:	8109.90.0000				
Australia		6	244	17	680
Belgium		14	190	13	290
Canada		35	4,460	63	3,790
China		7	201	3	212
Denmark		(3)	31	(3)	23
France		423	36,400	588	51,600
Germany		16	3,200	43	7,600
Japan		3	196	6	96
Sweden		(3)	131	6	248
United Kingdom		200	205	(3)	66
Other		3	280	1	105
Total		707	45,600	741	64,700
Unwrought hafnium powder and waste and scrap:	8112.92.2000				
Canada		1	173	(3)	14
China		--	--	(3)	4
France		2	670	4	827
Germany		(3)	37	(3)	44
Other		(3)	16	(3)	42
Total		4	895	4	931

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Harmonized Tariff Schedule of the United States.
[3]Less than ½ unit.

Source: U.S. Census Bureau.

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TABLE 5
ZIRCONIUM MINERAL CONCENTRATES: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	2001	2002	2003[e]	2004[e]	2005[e]
Australia	393,000	412,000	462,000 [4]	441,000 [4]	445,000 [4]
Brazil[e, 5]	20,553 [r]	20,000 [r]	29,900 [r, 4]	34,855 [r, 4]	35,000
China[e]	15,000	15,000	15,000	17,000	17,000
India[e]	19,000	19,000	20,000	20,000	20,000
Indonesia[e]	250	250	250	200	200
Malaysia	3,768	5,293	3,456 [4]	6,886 [r, 4]	3,500
Russia[e, 6]	6,500	6,500	6,500	6,500	6,500
South Africa[e, 7]	245,000 [r]	274,000	300,000 [r]	302,000 [r]	305,000
Thailand	-- [r]	--	--	--	--
Ukraine[e]	33,600	34,300	35,000	35,000	35,000
United States	W	W	W	W	W
Vietnam[e]	8,000 [e]	11,000 [e]	13,000	14,000	14,000
Total[8]	745,000 [r]	797,000 [r]	885,000 [r]	877,000 [r]	881,000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in total. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes data available through May 9, 2006.

[3]Small amounts of zirconium concentrates were procuded in various countries; however, information is not sufficent to estimate output.

[4]Reported figure.

[5]Includes production of baddeleyite-caldasite.

[6]Production of baddeleyite concentrate averaging 98% ZrO_2.

[7]Includes production of byproduct zircon from titanium sands mining and, until 2002, 15,000 to 20,000 metric tons per year of baddeleyite from Palabora Mining Co. Ltd.

[8]Does not include U.S. data, which are withheld to avoid disclosing company proprietary data.

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